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Mining and Metallurgical Section.

Stated Meeting, held Wednesday, February 13, 1901.

REMARKS ON THE EARTHQUAKE IN THE STATE OF COLIMA, MEXICO, JANUARY 19, 1900.

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On the night of the 19th of January, 1900, at 11.50 P.M., local time, a very severe earthquake was felt in Mexico over a comparatively narrow zone, extending, approximately, along the nineteenth parallel of latitude and reaching from the Pacific Ocean to the Gulf of Mexico.

It greatest force and longest duration were felt at Colima, on the Pacific Coast, where it lasted seventy five seconds. The duration and intensity diminished towards Veracruz, on the coast of the Gulf of Mexico, where it was scarcely perceptible, and where it seemed to disappear into the waters of the Gulf, as it had appeared from those of the Pacific Ocean.

The territory affected by the disturbance may be said to have been enclosed within the eastern half of an ellipse—or of a figure roughly approximating an ellipse—whose centre was at a point in the Pacific Ocean not far west of Manzanillo, latitude 19° 3′ north, longitude 104° 30′ west of Greenwich.

It is interesting to note that "it was in Manzanillo that were built, in 1564, the vessels composing the expeditionary squadron, which, under command of the gallant Don Miguel López de Legaspi, conquered the Philippine Islands."

This ellipse passed through, or close to, Rosario, Sinaloa, Aguascalientes, Dolores Hidalgo, Zacapoaxtla, Veracruz, south of Alvarado, Acatlán, Chilpancingo, Zihuatanejo. The line passing through these places may be considered as the extreme limit of movement, for at them it was not perceived by many persons, and beyond them nothing was felt.

The district most strongly affected was bounded by a concentric ellipse passing through, or close to, Cabo Corrientes, Autlán, Zapotlán (Ciudad Guzmán), Rio del Oro, Coalcomán, Boca de Apiza. In the district between the two bounding lines the intensity varied greatly according to the situation, and also, apparently, to local geological conditions. Friends at Puebla told me that they scarcely felt any motion.

Within the whole territory bounded by the outer limiting line there is only one distinctively active volcano, that of Colima. Indeed, there are only two in the whole of Mexico, Colima and Jorullo, in the State of Michoacán, about 300 kiloms. southeast of Colima.

Situated along the axial line of these ellipses, and grouped near its eastern end, are the principal extinct volcanoes of Mexico: Nevado de Toluca, Popocatepetl, Cofre de Perote and Citlaltepec, more commonly known as the Peak of Orizaba, which has now been determined to be the highest mountain in Mexico.

Popocatepetl has generally been considered extinct for centuries, and I have never seen smoke from it, although I have lived within sight of it for years; but I have been told

by friends who ascended it, that the fumes of sulphur are very strong on the leeward side of the crater, and that there is fire in crevices and holes far down in its depths.

In prehistoric times, which were probably not very remote, geologically speaking, Perote must have been a volcano of prodigious activity. There is a well-defined lava-flow extending from the mountain to the Gulf of Mexico, a distance of 80 kiloms. It is several hundred metres wide, but the width varies greatly at different places.

Mr. A. M. Wellington speaks as follows of these volcanoes in his paper on "The American Railway Line from Veracruz to the City of Mexico:"

"Orizaba is one of the three mountains in Mexico covered with perpetual snow, the other two being Popocatepetl (17,884 feet), and Ixtaccihuatl (15,705 feet) overlooking the valley. These, however, start from a plain 8,000 feet high, whereas, Orizaba starts practically from sea-level on the coast side, making it in that sense by much the highest mountain on the North American Continent, and among the highest in the world.

"(Mt. St. Elias, in Alaska, is a possible exception, being only about thirty miles inland, and its height variously given as 14,970 feet, 16,900, 17,850, over 18,000 [U. S. Census Report] and 19,500.)

"Its snow-clad peak is visible sixty miles at sea, long before there is any other evidence of land, and with the morning sun shining on it is a very striking sight. Its last eruption was in 1546, soon after the Spanish conquest, although it now occasionally throws out smoke. Only one or two men have ever ascended to its crater, the first having been Lieutenant Reynolds, U. S. A., in 1848. The line of the Mexican Railway passes to the south of the mountain.

"The 'Cofre,' or 'Box,' of Perote (so named from a cylindrical basaltic needle about 360 feet in diameter and 300 feet high which caps the mountain, like a box laid on its peak), although formerly one of the most active volcanoes in the world, and classed as still active, is perhaps permanently extinct, its last, and probably also its greatest,

eruption having been to form what looks to be, and is in fact, a frozen river of lava, extending to and running into the sea fifty miles distant, filling up an enormous barranca or deep gulch in the process, in a manner which was very convenient for subsequently carrying the line over it. The natural variations in the width of the gulch have caused lakes and frozen 'water-falls' of lava, which makes it difficult to believe, as one looks upon it from some commanding point, that the mass is not still flowing, making a unique and impressive bit of natural scenery. Vessels have frequently been wrecked on the toe of this flow where it enters the sea. It has still hardly any deposit of sand, soil, or vegetation on it, that and other facts evidencing that the flow is geologically very recent, not antedating much the historic era."

Perote is a spur of, and joined by a narrow ridge to its gigantic neighbor Citlaltepec, whose Aztec name "Star-hill" (from Citlatl, a Star and Tepetl, a hill) does not come from any sign of volcanic fire seen at the summit, but from the beautiful effect of the sun shining on the white, eternal snow of its almost perfect conelike peak, in the early morning or late evening, while the base of the mountain and all the rest of the country is shrouded in darkness.

The volcano of Colima was formerly active, but some time during the early part of the nineteenth century it became inactive and remained so till some time in the early '60's, since which time it has been constantly active. The eruptions consist principally of steam, or white smoke, great volumes of which puff out at short intervals, and take beautiful and capricious forms. When I was in Colima about twenty years ago, the puffs of vapor came at intervals of about twenty to forty minutes and were much larger than at present. Frequently, they would gradually roll up out of the crater, which is in the very apex of the almost perfect cone, and, expanding as they rose, form an inverted cone as large as, or even larger than, the mountain itself. At other times a straight column would rise thousands of feet above the crater and then its top would spread out like a gigantic umbrella, or mushroom.

Then again the vapors would take no definite shape, but roll out and pile up like an enormous mass of cumulus clouds, such as are often seen on summer afternoons. Frequently eruptions occurred about sunrise or sunset, and the effect of the rosy light of the "horizontal sun" shining on the mass of white vapor was indescribably beautiful and never to be forgotten. Especially was this so when seen through the graceful and rustling fronds of a grove of palm trees while the full moon was rising over the opposite horizon.

Of late years the amount of vapor seems to be less and it issues almost constantly without taking such fantastic shapes as formerly.

There are also frequent eruptions of red hot scoria, or sand, which at night show as streams of fire flowing down the mountain side for hundreds of metres. In the daytime they appear as trails of white smoke rolling down the slope. These streams of scoria do not run down the mountain side at random, but have clearly defined paths which can be seen from the city, 40 kiloms. away, and which look like troughs or gutters. They have many branches and gradually grow smaller as they descend. In time the accumulation of ashes at the crater becomes so high and unstable that it falls and covers the channel, or it is destroyed by a slide farther down the mountain. Then a new course is soon formed which in turn is destroyed.

During the period of inactivity of the volcano frequent earthquakes were felt in Colima. They reached their greatest intensity about 1847 or 1848 when there was much destruction of property. I was told by a gentleman who was 11 years old when that earthquake occurred, and remembered it perfectly, that the inhabitants were so much frightened that for many weeks they slept in booths or "shacks" set up in the courtyards of their houses, being afraid that the roofs might fall on them if they slept indoors. The same gentleman told me that the earthquake of that year was not so severe, according to his recollection, as the present one. There was also a very serious earthquake earlier in the century, about 1808, and from all

accounts it must have been fully as severe as this and perhaps even more serious.

After the volcano became active the intensity of the shocks diminished and they became less frequent, although several were felt every year. I felt several slight tremors in 1880 and 1881 but they wrought no destruction. During the last four or five years they have increased in force and have caused more damage. That of 25th or 27th January, 1899, which was quite strong in Mexico City and Puebla, was also felt with force in Colima.

It will be noticed that in two consecutive years the shocks occurred about the same day in January, and the people of Colima consider that January and February are earthquake months. At some time during those months they always expect a severe earthquake, after which—if they have suffered no harm—they feel comparatively easy for another year, for two seldom occur in the same season.

January is about the middle of the dry season, which begins in October and lasts until May or June. Severe shocks rarely occur during the rainy season—at least in Colima.

The summit of the volcano of Colima is about 3,960 metres above sea level, and about 75 kiloms. in a straight line from the Pacific Coast. It is about 40 kiloms. to the north of the city of Colima. The city is about 500 metres (at the Plaza) above sea level, and the rather steeply sloping plain on which it is situated is diversified by many watercourses and low rolling hills. It is separated from the foot of the mountain by a deep valley and a range of low hills.

The mountain is a double peak, that to the north being the higher and covered with forest to the top. As it is frequently covered with snow in winter it is called "El Volcan de Nieve." The southern peak, which is quite a regular cone, is "El Volcan de Fuego," the Fire Mountain. The two are joined some distance below their summits by a narrow ridge or "hog-back."

The crater of the volcano is at the very apex, and for several hundred metres down the sides are covered with loose scoria and sand, over which it is impossible to walk. The inclination is also very steep.

In geological times the two must have been very active, or else have formed one immense volcano, for the country far below the city is covered with loose, vitrified stones, which vary in size from pebbles to rocks of many cubic metres. All of these are apparently of volcanic origin and not water-worn; moreover, they undoubtedly seem to have been thrown to where they are found by the force of eruptions and not to have been carried by water, for they are as frequently found on the tops of hills at long distances from any sign of water action, as in the valleys and along watercourses.

Near the foot of the mountain, and not far from Zapotlán, an extensive stretch of country is covered by an ancient lava-flow. But, as scattered through it are many cupshaped depressions which look like old craters, this flow seems to have been local in origin and not to have come from the volcano, from which it is separated by a deep ravine.

Owing to intervening buildings I could not see the volcano from the house in which I lived, so could not make any personal observations on the character of the eruptions. But, as far as I could learn from friends, there had been no noticeable change in them for several days before the earthquake, nor were the shocks accompanied with any diminution or increase in their volume and frequency.

At the Roman Catholic Seminary in the city of Colima, careful observations are taken several times daily, and these show that there was little or no change in the eruptions either before or after the earthquake. Other observations taken at the same observatory show no meteorological disturbance accompanying the phenomenon.

The barometric means (reduced to O) were as follows:

Mean for the month	718 mm. 90
11th January, daily mean	717 mm. 77
18th " " "	717 mm. 56
19th " " "	717 mm. 76
24th " " "	717 mm. 12

This last was the lowest daily mean for the month.

The temperature was rather high for the time of year, being 29°9 C. during the day, and 15°8 at 9 P.M.

A night or two before the sky had been thickly covered with small, floculent clouds which are supposed to look like sheep, whence the Spanish name "cielo aborregado." This appearance of the sky is somewhat like that known here as "Mackerel Sky," but the clouds are rather more fleecy. The "cielo aborregado" is said to be a sure sign of a coming earthquake. Of the other supposed precursory signs, as a certain indescribable haziness of the atmosphere, similar to that of "Indian summer," and also an oppressive calmness and hush over everything, I noticed nothing, and although at the time of the shocks there was no wind, it was a perfectly natural calm.

The plan of the streets of Colima is, practically, rectangular and, while they are by no means perfectly straight, their general direction is north to south and east to west. The mountain is nearly north from the Plaza. Nearly all the houses are of one story, most of them built of adobe and roofed with heavy horseshoe tiles of baked clay. The façades are generally crowned with a heavy, projecting cornice of bricks and mortar. Some of the houses are constructed of wickerwork woven on posts imbedded in the ground. This is plastered with clay and whitewashed, thus making a very presentable and cheap house which is nearly earthquake-proof. Around the Plaza and scattered through the town, there are a few two-story houses, built of brick. The roofs of the more pretentious houses, and of some others built of masonry, are often vaulted or domed; the domes being made of hollow, baked-clay cylinders — or, more properly, frustrums of cones—with the ends closed and the whole plastered over.

The Colima River flows from north to south through what would be approximately the geographical centre of the town but rather to the west of the principal business portion and of the Plaza. It is a small stream, carrying, in the dry season, 500 or perhaps 1,000 litres per second. East of the Plaza are two or three small runs, also flowing from north to south, and practically without water in the dry season. The northern part of the town is much higher than the southern; but as far as could be seen, in the

absence of cellars or excavations, there appeared to be no important difference in the subsoil.

The evening of the earthquake, as I walked through the Plaza, about 11 o'clock, I was particularly impressed by the beauty and tranquillity of the night and by the brilliancy of the moonlight. I was asleep shortly after quarter-past eleven, for the last thing I can remember, just as I was losing consciousness, was the town clock striking the quarter hour.

Suddenly I awoke possessed by a nameless dread. The room seemed filled with a low, indistinct rumble, a scarcely audible pulsation, which came from beneath, from above, from all around. As it grew it sounded like the noise of a heavy wagon moving over a frozen road some distance away. Almost before I was awake I realized that it was an earthquake. As yet I had not noticed any movement of the earth although I slept on a light canvas cot sensitive to any motion. At other times I had never run out of the house during an earthquake, but this time, almost before I knew what I was doing, I had rushed out of the room, fortunately on the ground-floor, to the "Pila" (fountain) in the center of the "Patio" (courtyard) of the house. Almost at the same time our two "mozos" (servants) who slept in the hallway of the great house-door, reached the pila. Although both were natives of Colima and consequently more or less accustomed to earthquakes, their faces, plainly visible in the bright moonlight, were pictures of abject terror. The first severe shock had scarcely begun when we reached the pila, but by the time my companion could get out of his room, only a moment or two after us, the motion was very strong and it was really quite ludicrous to see his frantic efforts to run. His actions were very much like those we all make when trying in the dark to reach that delusive top step which we always find is not where we expected it to be.

At first the motion appeared to be a slight, slow oscillation from west to east, rapidly becoming faster and more violent until a climax was reached, when it suddenly died away only to be repeated three, four or five times—I could

not count. After the first motion, from west to east, it changed to north and south, and then to trepidation. When I reached the pila I was facing south and, with my feet spread well apart, fearful lest the ground should open under me, was able to withstand the first shock; when, however, the motion changed to north and south I was nearly thrown head first into the pila and had to steady myself by putting my hand on the man who was standing beside me, facing west.

The pila is a round, stone basin about 1 m. 75 in diameter and 0 m. 75 high, all above ground, with a stone pillar in the centre for the pipe of the jet. Although full of water at the time it was nearly emptied by the motion, the water being thrown out on the east and west sides. The same thing happened to the fountains in the Plaza. I imagined that I could see the ground move in small, rippling waves which ran across the pavement of the patio, but concluded it must have been an optical delusion caused by my excitement until, the next day, a friend told me that he also had distinctly seen waves run across the pavement of the plaza, where he was at the time.

The following description, from a letter written the next day, while the impressions were fresh in my mind, will give a more vivid picture, perhaps, than anything written later:

"First there came a gentle heaving and little, rippling waves, with not much sound, but increasing and augmenting until the whole earth seemed to be rocking and swaying in waves that proceeded from west to east, while at the same time it seemed to fly up at me. This died away somewhat, and then increased to more than at first, again dying away and increasing with redoubled fury three or four times.

"The whole while there was the accompaniment of the most infernal din under ground—a sort of rrr-RRR-*RRR*—mixed with the shrieks of the neighbors, who were pouring out of their houses into the streets, the crash of falling cornices, the clang of church bells set in motion by the swaying of the towers, the howling of dogs, the stamping and screaming of frightened horses and other domestic

animals. To these may be added the groaning of the earth, and the grinding of the stones and bricks in the walls of the houses.

"The movement gradually died away with a few shivers and slight tremors, but the hanging lamps and flower-baskets kept on swinging for a long time. The nearest thing to which I can liken the quake is to the shaking of a large rug by two or four persons. They take it by the corners and give a few preliminary shakes to see if they have strong hold of the edge; then they shake vigorously and with increasing violence; stop a moment to take breath and shake again three or four times.

"According to the records at the Observatory it lasted only seventy-five seconds; but that is a long time for an earthquake. After we felt assured that it was over we examined the house and belongings. We found no cracks in the walls (which were of masonry and not adobe) that were worthy of consideration, and only one vinegar bottle and one goblet were broken. Several bottles and small articles were moved somewhat out of place and the water had slopped out of the washbasins.

"Finally, after dressing, I started out to see what had happened to the rest of the town, the moonlight being almost as bright as day. The streets were alive with frightened people. I walked to the Plaza. In the street by the cathedral was a lot of bricks, stone and mortar which had fallen from the towers, and we could see that one of the great iron crosses surmounting one of the towers was gone; but it was not light enough to see how badly the edifice was cracked. The low clock-tower on the roof of the Palace was badly cracked and the hands of the clock had fallen into the street. The stone—brick and mortar—balustrade on one of the houses on the south side of the plaza was destroyed and had fallen into the street. (Similar balustrades on houses on the north and west sides of the plaza—there were none on the east—were not injured.)

"I found a friend, who lives in a house on the plaza, standing with his family in front of his door. I went through the house with them. Several glass things had

been broken and nearly all the large earthenware flower-pots in the patio were overturned and broken. In the parlor a large glass-covered portrait had fallen on a 'what-not' which it smashed, but the picture we found on the ground leaning with its face against the piano, the glass unbroken.

"The 'O's,' who live in a great, rambling, one-story house with a tile roof, a couple of blocks from the Plaza, were all in the street receiving the congratulations of their neighbors because they had no damage but a fallen cornice to lament.

"The new two-story house a block above the office, into which a friend had just moved with his bride, was a complete wreck.

"I wandered about a little more, finding every house open and the people preparing to spend the night in the streets, some for fear of another shock, and others because their houses were not safe. In the morning we could see much more of the damage. The great dome of the cathedral was cracked in a dozen places, the two bell towers that flank the façade were very much shattered, and the whole building was cracked, both front and back, from cornice to foundation."

This church was destroyed by the earthquake of 1847, and had only been rebuilt and reconsecrated some ten or fifteen years ago.

"On every side through the streets lay bricks, adobes, mortar and tiles, and many houses showed cracked walls.

"The seminario is in a horrible state. There is not a wall in the building that is not badly cracked. All the houses of the poorer sort are one-story with tile roofs and no ceilings, and, as I walked along the streets, I could see through the open doors and windows that there was scarcely a roof from which the tiles had not been shaken, so that one could see the sky through the roof. Many have collapsed completely."

Early next morning the Governor appointed a commission (one member of which was a Mexican engineer, a graduate of Lehigh University, on a business visit to Colima) to examine and report on the condition of the public build-

ings. They recommended the closing of the six churches of the city until repairs which they indicated should have been made. They also practically condemned the cathedral, and within a few days workmen began to erect the scaffolding to take down the towers and to support the dome till further arrangements could be made. Of the schools they reported: Three in complete ruin, two dangerous, ten badly damaged but not dangerous nor difficult to repair, and four unharmed. The palace, although it adjoins the cathedral, was unharmed. The jail, prison and police barracks were slightly cracked, the hospital more so, and the theatre not much. The eight large gateways to the square called the "Jardin Nuñez" were badly shattered, but none fell. The arches seemed to have been sliced off the pillars at the springing line, and the tops of the pillars forced outward a couple of inches.

In Mexican architecture the top of doorway and window openings is generally an arch, either flat or circular. Where the building was racked these arches were broken at about the haunches, or thirds, and the central portion slipping down acted as a wedge to force the wall open and also to prevent it from coming together again when the motion of the earth ceased.

The main arches forming the ribs of the vault of the cathedral roof were cracked in the same way, and when I went up the next morning at first I was afraid to walk across the roof.

Most damage was done in the part of the city lying north of the plaza. In the lower ground on the south of the plaza fewer houses were injured.

Up to noon of the 20th, seven persons killed and seventy-seven wounded had been officially registered in the police reports; but there were also many wounded who remained in their own houses and were attended by their own doctors, of whom no report was made to the authorities.

Shortly after midnight there was another slight shock, but it was not perceived by many persons and, as the seismograph was in the wrecked seminario, there was no official record of it.

For many nights—nearly a month—a great part of the population moved beds out into the streets and slept there. Notwithstanding that our house was intact and the roof in good condition, I confess to feeling an uneasiness and dread when bedtime came. However it wore off in time and things returned to their normal condition in two or three weeks.

In the country outside of the city the condition of things was very bad also. On many of the haciendas the buildings were wrecked and the dry stone fences enclosing the fields were thrown down. The damage from this cause alone amounted to thousands of dollars.

A gentleman who was at his hacienda that night told me that the bellowing of the cattle in the fields and the noise of the wild animals in the nearby mountains was perfectly awful and appalling.

I did not hear of the ground cracking open anywhere near the city; but toward the coast it opened in several places. It was said that, from some of them there was an outflow of sand. I saw nothing of the kind however.

The railroad suffered very little. At several places the sides of rock cuts were badly shattered and some loose rocks fell on the track. They continued to fall occasionally for some time (weeks) afterwards. It was, however, impossible to tell which of the cracks were new and caused by the earthquake and which were old ones from blasting during construction and had not been noticed until our attention was especially called to them. The rock was mostly very hard, vitreous limestone.

On two or three stretches, where the road had been built across the laguna and marshy ground on trestles which were afterwards filled in, the banks, although eight or ten years old, settled somewhat, and had to be filled in and resurfaced. Otherwise the track was not disturbed. The large steel through bridge carried across the Armeria River on high masonry piers showed no sign of injury. The two massive stone arch street bridges in the city—one of them very old—were uninjured, although I have felt them tremble from the force of the rushing water during a flood.

Not far from the city, in a field which has been under cultivation for generations, a hole was discovered after the earthquake and upon investigation it was found to be a short shaft at the foot of which were several subterranean chambers containing human bones and other relics which showed that the place had been a tomb of the aborigines—probably of the Aztecs—who passed through Colima during their eight centuries of wandering from "Aztlán," the place of their origin, to Tenochtitlán, their final resting place in the valley of Mexico.

The record of the seismograph shows that the greatest amplitude of oscillation was in an east and west direction. With few exceptions, all the cornices which fell were those of houses on the west side of the streets. To me this seems to indicate that the first shock, before the whole fabric began to sway in unison, came from the west and that the wall was sufficiently elastic to allow its base and lower portion to move to the east under this first impulse, while the heavy and rather unbalanced cornice retained its position in space (through inertia) until, losing the vertical support of the wall, it toppled over. The two or three exceptions were houses on the southside of the streets.

The large "regulator" clock, with compensating mercurial pendulum, which hung in the office, on the north side of a heavy masonry wall running east and west, did not stop. But, when I looked at it just after the shocks had ceased, the pendulum seemed to have greater amplitude of swing than usual. When compared with Mexico by telegraph the next day we found it had gained one or two minutes. A smaller pendulum clock hanging on the west side of a north and south wall had stopped at the hour of the earthquake. In other houses clocks hanging in the same relative positions were similarly affected.

While the motion was not perceptible to the unaided senses outside of the bounds already mentioned, it was accidentally noticed by an observer far beyond them, as is shown by a letter to *Science* (9th February, 1900) from Mr. R. H. Tucker, of Lick Observatory, Mount Hamilton, Cal., who noticed oscillations in the mercury, evidently produced by

this earthquake, upon setting the telescope for the nadir observation.

It is almost, if not absolutely impossible, for a person who has never felt an earthquake, to appreciate to the fullest extent its supreme awfulness. At first there is a momentary feeling of wonder and bewilderment, and then, when the mind fully realizes what is happening, that the solid earth is moving under one's feet—that the earth, which all our lives we have been taught to consider the very symbol of stability and immobility, is shaking and heaving like a troubled sea, terror and dread overpower all other emotions.

Happily, I never have had to face the elements in their more common manifestations of destructive force—fire, flood and wind; but it seems to me that in any of them a man has a "fighting chance," while in an earthquake there is absolutely nothing to do. One knows not which way to turn, whither to flee for safety, and in consequence feels utterly helpless.

It is terrible to think of what would happen in cities like New York, Philadelphia, Chicago and others in which there are so many "sky-scrapers." Braced as they are, within themselves and by neighboring buildings, it is not probable that the steel frames of these buildings would collapse; but it is not improbable that the outer shell would disintegrate, and the loss of life from falling brick and tiles, as well as from the ensuing panic, would be horrible.

PHYSICAL SECTION

Stated Meeting, held December 26, 1900

RECENT ADVANCES IN THE PHYSICS OF WATER.

GEORGE FLOWERS STRADLING, PH.D.
Member of the Institute.

For a long time it has been known that water, the most common of all liquids, has physical properties which vary widely from those of most other liquids. The large quantity of heat required to melt a gram of ice, the still larger quantity required to convert a gram of water into vapor at the same temperature and the existence of a temperature of maximum density between the melting and the freezing points, mark water as departing from the usual rules of liquid comportment. Already the list of the anomalies presented by water is long and yet it is no uncommon occurrence to have it increased. For instance Hauser in the July number of *Drude's Annalen* for 1901 shows that at 32° C., the viscosity of water is not changed by a pressure of 400 atmospheres, while at other temperatures it is changed.

Within the last decade serious attempts have been made to furnish an explanation of the irregularities of water. The idea that water molecules are not H_2O simply but are aggregates of this group is advanced by Raoult * as a result of his experiments upon the molecular lowering of the freezing point of solutions, and probably expressions of this view could be found long before. When in 1891 Roentgen attacked the problem he used this suggestion and succeeded in furnishing a qualitative explanation.†

He regards water as composed of molecules of two kinds, which he designates ice molecules and molecules of the second kind. Ordinary water is considered to be a

* Raoult, *Ann. chim et phys.*, Series 6, Vol. II, p. 66, 1884.

† Roentgen, *Wied. Ann.*, XLV, p. 91. "Ueber die Constitution des flüssigen Wassers."

saturated solution of ice molecules in a mass of molecules of the second kind. By the addition of heat ice molecules are converted into those of the second kind. This is accompanied by a diminution of volume, just as when ice melts.

The maximum density of water.—At 4° C. water is at its maximum density. The addition of heat to a mixture of the two kinds of molecules will cause

(1) A diminution of volume due to the change of ice molecules into molecules of the second kind.

(2) An increase of volume due to the expansion of the mass of molecules of the second kind.

The observed change in the volume of water is the difference of these two effects. When heat is applied to water at 0° a relatively large number of ice molecules are changed into the other kind and the diminution of volume amounts to more than the increase. As the temperature rises the number of ice molecules diminishes, hence fewer are changed into the second kind, and the difference between the diminution and increase grows less. At 4° the two effects just balance each other, while above this temperature the increase of volume is the greater.

Roentgen gives this explanation but does not claim to be the originator of it. Indeed H. M. Vernon* in the same year gave practically the same explanation.

Pressure—Volume—Temperature Relations of Water.—As the temperature of simple liquids rises, their compressibility increases, but the compressibility of water grows less with rising temperature and, according to the results of S. Pagliani and G. Vicentini,† reaches a minimum value at 63° C.

To explain this Roentgen further assumes that an increase of pressure upon a mass of water kept at constant temperature results in the change of some of the ice molecules into molecules of the second kind, and that the num-

*H. M. Vernon, *Phil. Mag.*, Series 5, Vol. XXXI, p. 387, 1891. "On the Maximum Density of Water."

†S. Pagliani und G. Vicentini. *Beiblätter*, VIII, p. 794. "Ueber die Compressibilität der Flüssigkeiten und insbesondere des Wassers."

ber so changing is greater as the total number of ice molecules present is greater. This transformation causes a diminution of volume which is greater for a given increase of pressure at low temperatures, because then the water is richer in ice molecules. When, therefore, pressure is exerted upon a mass of water, the resulting change of volume is the sum of

(1) A decrease of volume due to the transforming of ice molecules into those of the second kind, and

(2) A decrease due to the compression of the mass of molecules of the second kind.

The first of these decreases will grow smaller as the temperature rises, because with rising temperature the number of ice molecules becomes smaller. On the other hand the second will probably become greater as the temperature goes up. At least simple liquids act thus. From the opposite effects produced upon the two decrements by a rise of temperature it is seen that their sum, which is the actually observed compressibility of water, might at some temperature have a minimum value.

The effect of pressure upon the coefficient of thermal expansion of ether, carbon disulphide and alcohol is to lower it; but for water it has been found that the mean coefficient up to 50° at least is increased, even when the pressures amount to 2500–3000 atmospheres. To find an explanation for this anomalous effect, consider how an increase of pressure will act on both of the volume changes mentioned under the heading "The maximum density of water." The first, the diminution of volume, will be made less by an increase of pressure, because thereby the ice molecules are converted into the other kind, so that there remains fewer of them to be changed by heat. Roentgen had no data by which to determine how pressure would affect the second, the increase of the volume of the mass of molecules of the second kind. He suggests that perhaps there would be but little effect upon the coefficient of expansion. Let us now compare the thermal expansion of a mass of water under a pressure of one atmosphere with the expansion under a higher pressure, the rise of temperature

being, for example, from 5° to 10° C. in both cases. The observed expansion under both pressures is the expansion of the aggregate of molecules of the second kind minus the decrease in volume due to the change by heat of some ice molecules into the others. Under the higher pressure the minuend is larger because there are more molecules of the second kind in the water, and the subtrahend is less because the number of ice molecules is smaller. The remainder, the observed thermal expansion, is therefore larger for the higher than for the lower pressure.

Amagat finds that at high pressures water comports itself as an ordinary liquid. This finds its explanation in the disappearance of ice molecules. His results likewise show that the effect of pressure upon the coefficient of thermal expansion is most marked when the temperature and the pressure are low. This is understood when it is recalled that the number of ice molecules is greater at low pressure and at low temperature.

Lowering of the temperature of maximum density by pressure.—The temperature of maximum density moves downward from 4° C. as the pressure upon the water is made greater.

According to the view already advanced, at 4° C. and under atmospheric pressure the effect upon the volume of a mass of water caused by a small increase of temperature is zero, because there the two opposite volume changes just balance each other. An increase of pressure lessens the number of ice molecules and consequently gives to the expansion of the mass of molecules of the second kind the preponderance. Under this increased pressure, then, the balancing of the two effects no longer occurs at 4°, but at some lower temperature, where the water is richer in ice molecules.

By pressure water can be cooled below 0°C. without freezing, because the pressure prevents the formation of ice molecules.

Viscosity of water.—Water under pressures of several hundred atmospheres is less viscous than at normal pressure, provided the temperature does not exceed 32°C. Other liquids which have been investigated grow more viscous with an increase of pressure.

The viscosity of water is generally made greater by dissolving other substances in it, and the larger the quantity of the solute the greater in general is the viscosity. Its viscosity would accordingly be expected to increase with the proportion of ice molecules. An increase of pressure by reducing their number would reduce at the same time the viscosity. An increase of temperature lowers the viscosity for the same reason, and very likely also by decreasing the viscosity of the mass of molecules of the second kind.

From the investigations of R. Cohen* it appears that the decrease of viscosity produced by a given increment of pressure is greater the lower the temperature. For instance, at 10°C. the effect of an increase of pressure of 600 atmospheres is about six times as great as at 23°C. This is to be attributed to the greater effect at 10° of the pressure in reducing the number of ice molecules. Moreover, when the temperature is constant, he finds that a given increase of pressure produces a greater effect upon the viscosity when the pressure already exerted is small than when it is larger. As an illustration, when the temperature is 15° an increase of pressure from 100 to 300 atmospheres produces a larger decrease in the viscosity than an increase from 300 to 600 atmospheres. The reason of this is to be found in the larger proportion of ice molecules present at low pressures and the consequent greater reduction in their number produced by the added pressure.

These results obtained by Cohen are of especial interest since they form the fulfilment of a prediction made by Roentgen "that the viscosity of water at high pressures will be less reduced by a given increase of pressure than at low pressures" and "that the effect referred to will for equal pressures be found to be the larger the lower the temperature of the water is."

Following the road marked out by Roentgen, a number of investigators have succeeded in finding the explanation

* R. Cohen. *Wied. Ann.*, XLV, p. 666, 1891. "Einfluss des Druckes auf die Viscosität von Flüssigkeiten."

of some of the irregularities of water which he did not discuss. Hugo Witt * of Stockholm has applied the theory of ice molecules to several phenomena of aqueous solutions.

From the equation of equilibrium between the two kinds of water molecules in an aqueous solution, he infers that the presence of a solute has the effect of causing some of the ice molecules to change into those of the second kind. This at once explains why the volume of an aqueous solution is generally less than the sum of the volumes of the water and of the dissolved substance. The contraction is the result of the change of molecules of greater specific volume into those of less.

We have seen that an increase of pressure lowers the temperature of maximum density of water. Now both pressure and the presence of a substance dissolved in water have the effect of reducing the number of ice molecules, and hence it is seen why the temperature of maximum density of an aqueous solution is below 4° C.

Witt explains the high specific heat of water as due to the heat required to change the ice molecules into those of the second kind. Aqueous solutions nearly always have a lower specific heat than water. Even after making allowance for the solute, whose specific heat is of course less than that of water, it is found that the water in the solution seems to have a less specific heat than before the substance was dissolved in it. Witt attributes this to the solution's having fewer ice molecules than water, so that a rise of temperature of 1° will be followed by the transformation of fewer ice molecules and will therefore require a smaller quantity of heat. He finds in the heat requisite to change the ice molecules into the other kind a reason why the solution of substances in water is usually accompanied by a lowering of temperature.

When a solid is dissolved in a liquid there is a decrease in the vapor tension of the liquid. Raoult has shown how

* Hugo Witt, *Öfversigt af Kongl. Vetenskaps-Akademiens Förhandlingar*, 1900, No. 1, p. 63. "Ueber die Constitution des Wassers."

to calculate this decrease. Now, when water is the solvent, Witt found that, even after allowing for the dissociating power of water, the observed lowering of the vapor tension is more than that calculated by Raoult's formula. He gives this explanation. There is reason to believe that the vapor tension of the ice molecules is greater than that of the others. The observed vapor tension of water probably lies between the two values. When a salt is dissolved in water, by its presence it occasions a lowering of the vapor tension; but in addition to this it causes some ice molecules to change into the second kind and thus the vapor tension is still further lowered. This last effect is not included in the formula of Raoult.

J. J. van Laar, of Utrecht,* in a mathematical paper reaches the conclusion that water is made up of $(H_2O)_2$ groups which dissociate with rising temperature. He explains the occurrence of a temperature of maximum density for water very much as Roentgen does. The contraction of volume resulting from the mixture of alcohol and water he accounts for thus: Both have complex molecular groups formed by association of the molecules represented by the respective chemical formulas, and in both cases change from the complex to the simple form is attended by a shrinking of volume. When the two liquids are mixed both lose in complex molecules and gain in simple ones. Hence the volume decreases. He calculates that the change of 18 g. H_2O into $(H_2O)_2$ causes a lessening of the volume by 8·4 cm^3.

In the experiments by Cohen referred to above it is shown that aqueous solutions of NaCl, which are not concentrated, suffer no change in viscosity by the application of a pressure of 600 atmospheres, at a certain temperature for each strength of solution. Below that temperature the viscosity is lessened; above it is increased. Now the behavior of water is the same† except that the temperature

*J. J. van Laar, *Zeitschrift für physikalische Chemie*, XXXI, p. 1. "Ueber die theilweise Association der Flüssigkeiten."

†L. Hauser, *Drude's Annalen.*, V, p. 597, 1901. "Ueber den Einfluss des Druckes auf die Viscosität des Wassers."

of no effect is higher. We can find an explanation of this downward displacement of the temperature by recalling that, in accordance with the ideas of Witt and van Laar, the number of ice molecules in water at a certain temperature is the same as the number in a solution of salt in water at a lower temperature.

Within the past year a paper by Sutherland* has appeared in which a vigorous and successful attempt is made to furnish a quantitative explanation of the anomalies of water. The author aims to show that steam consists of H_2O, ice of $(H_2O)_3$ and water of a mixture of $(H_2O)_3$ and of $(H_2O)_2$. He calls H_2O hydrol, $(H_2O)_2$ dihydrol, and $(H_2O)_3$ trihydrol. According to this nomenclature Roentgen's ice molecules are trihydrol and his molecules of the second kind dihydrol. The chief results of the paper in the calculation of the physical constants of dihydrol and of trihydrol are given in the following table:

	Density, ρ_0, at 0° C.	$\rho_0 = \rho t\,(t - kt.)$ Temp. Coeff. k.	Compressibility per Atmosphere at 0°.	Surface Tension at 0° in Dynes.
Dihydrol . . .	1·08942	·0009	·000016	78·3
Trihydrol . .	·88	·0002	·000010 (?)	73·3

	Critical Temperature.	Specific Heat at 0°.	Latent Heat of Fusion.	Latent Heat of Evaporation.	Viscosity at 0°.
Dihydrol . . .	368° C.	·8	—	257 cal.	·0030
Trihydrol . .	538° C.	·6	16 calories.	250 cal. approx.	·0381

The method of determining the density of one of the ingredients of water will now be given to serve as an example of Sutherland's manner of procedure. A curve is plotted in which the ordinates are the densities of water and the abscissas the corresponding temperatures. The curve has its maximum ordinate of 4° and then sinks toward the axis of X, appearing to approach a straight line asymptotically. It seems reasonable to take this straight line as giving the

* Sutherland, *Phil. Mag.* Series 5, Vol. L, p. 460, 1900. "The Molecular Constitution of Water."

density—temperature relations of one of the ingredients of water. Following the line back until it meets the axis of Y, the density at 0° is read off as 1·083. From considerations based on surface tension it is later shown that this ingredient is dihydrol.

Mendeléeff has calculated an equation giving the density of water as a function of the temperature. Sutherland throws this equation into a form in which the density is the sum of five terms. By regarding water at any temperature as a mixture of water having the composition which it possesses at 4° and of additional dihydrol, and further by assuming that both of these ingredients expand with heat in a similar and simple manner, he obtains another expression for the density of water at any temperature which also has five terms similar to those of the transformed Mendeléeff formula. From comparison of like terms of the two formulas it follows that the density of dihydrol at 0° is 1·08942, which agrees well with the value 1·083 found from the curve. It will not escape notice how much this result rests upon assumptions.

The following table shows the parts by weight of trihydrol in water at different temperatures under pressures of 1 and 150 atmospheres respectively.

t	0°	20°	40°	60°	80°	100°	120°	140°	198°
At 1 atmo. .	·375	·321	·284	·255	·234	·217	·203	·191	·165
At 150 " . .	·351	·300	·264	·237	·217	·203	——	——	——

It is calculated that at 2,300 atmospheres pressure there would be no trihydrol in water at 0°.

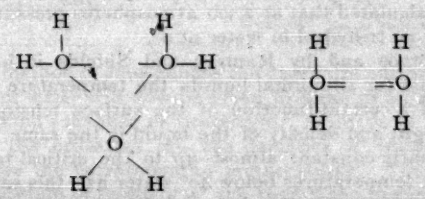
By Eötvös and by Ramsay and Shields it has been proved that for all normal liquids the temperature rate of change of a certain function of the surface tension, molecular weight and density of the liquid is the same and remains nearly constant almost up to the critical temperature. At temperatures below 40° water has this same constant provided the density and molecular weight of trihydrol, and not those of water as ordinarily understood, are taken. From 60° upward the same constant is approached if the density and molecular weight of dihydrol are used. Therefore up to 40° the surface layer of water

consists of trihydrol alone and beyond this dihydrol forms in greater and greater quantity with ascending temperature. The reason why the surface film differs in composition from the body of the water is that in the film tension manifests itself, and, if pressure converts trihydrol into dihydrol, then tension should produce the opposite change. Above 60°, however, the surface tension is so far reduced as to permit some dihydrol to form.

Sutherland says "The solubility of substances in trihydrol may be different from that in water." In connection with this the experiments of Jan von Zawidski* are of interest. He found that foam from aqueous solutions of acetic and of hydrochloric acids containing also some saponin was slightly richer in the acids than the body of the liquid, and that the difference of composition showed itself to a very marked degree in saponin solution by itself.

Sutherland regards the heat of fusion of ice as including the heat required to dissociate some trihydrol into dihydrol. This also holds for the specific heat of water. The latent heat of vaporization likewise includes the heat of dissociation of dihydrol into hydrol. It is calculated that 189 small calories are needed to change 1 gram of dihydrol into hydrol, at 100° and 177 to change 1 gram trihydrol into dihydrol at 0°.

Sutherland suggests these graphic formulæ for trihydrol and dihydrol in which o has valency of 4.



The hexagonal form of ice crystals seems to be the most probable grouping to be expected of molecules in which

*Jan von Zawidski. *Zeit. fur phys. Chem.*, XXXV, p. 77. "Zur Kenntniss der Zusammensetzung der Oberflächenschichten wässeriger Lösungen."

the equilateral triangle marked out by the three oxygen atoms is the chief feature.

The problem confronting Sutherland was this: Given a substance, whose behavior, especially as a liquid, is anomalous in a number of respects, to determine what must be the respective quantities, rates of change and physical constants of two simple and normal substances, by whose mixture the comportment of water shall be reproduced. Of necessity he often makes appeal to analogy with ordinary substances, for it is one of the conditions of the problem that the solution shall be in terms of such substances. Hypothesis often confronts the reader where he could wish for something firmer, yet the longer he reads the paper the surer he becomes that at last a scientific and quantitative explanation of the comportment of water exists.

G. Tamman * has found that in addition to ordinary ice there are two other varieties, II and III. They differ from the common kind in these respects.

(1) Their melting points are raised by the application of pressure, whereas the opposite is true of ordinary ice.

(2) Their density is greater than that of water. This accounts for the effect of pressure upon their melting points.

(3) They are formed only under special conditions of temperature and pressure. Common ice is cooled below —22° C. and the pressure raised to at least 2,400 kilograms per cm.^{2} Now if the temperature is further lowered until it is from —30° to —60° C. ice III forms; if it is lowered to —80° C. ice II forms.

When ordinary ice changes into ice II the following diminutions of volume per gram occur.

—73°	·171 cm.^{3}
—55°	·180
—34°	·193

The heat of transformation of common ice into ice II or ice III is positive or negative or zero according to the tem-

* G. Tamman, *Drude's Ann.*, II, p. 1. "Ueber die Grenzen des festen Zustandes," IV.

perature. The lowest temperature at which Tamman observed water and ice to exist together was —22·4° C., the pressure being 2,230 kilograms per cm.² He gives the following table of the temperatures at which ice is melted at the accompanying pressures.

—t°	1°	2·5°	5°	7·5°	10°	12·5°	15°	17·5°	20°	22.1°
Pressure kg. per cm.	1	336	615	890	1155	1410	1625	1835	2042	2200

It appears that the lower the temperature the less is the additional pressure requisite to produce a further lowering of the melting point by 1°.

When we reflect for how long a time air and water have been the objects of scientific investigation it is indeed remarkable that they both still richly repay re-examination.

I take the liberty of quoting here a paragraph in a letter from Mr. Hugo Witt to me. "It seems to me to be a great mistake first to study aqueous solutions and then other solutions. Water is, as I believe to have shown, and as Roentgen, van Laar and others believe (Professor Arrhenius believes also, he has told me, in the ice molecules) a very complicated substance, and there must in the process of solution in water be great exceptions from the simple rules which exist for other solvents that are not associated. And the chapter in treatises on physical chemistry, "Theorie der Lösungen' should rightly be entitled 'Theorie der Wässerigen Lösungen.'" Not only in the matter of solutions but in other more strictly physical relations it is a misfortune that the role of the typical liquid was assigned to water.

PHYSICAL SECTION.

Stated Meeting, held Wednesday, December 26, 1900.

NOTES ON MAGNETIC CURVES.

By Jesse Pawling, Jr., B.S.

The following are solutions of examples 37, 38 and 39, page 51, of *Minchin's Statics*, Vol. I, fifth edition.

"37. Given the base, $N\ S$, of a triangle $N\ P\ S$,* and also the sum of the cosines† of the base angles, $S\ N\ P$ and $N\ S\ P$; let the curve locus of P be constructed. Prove that if a particle be placed at any point of the curve and acted on by two forces, one repulsive form N and equal to

$$\frac{\mu}{N P^2},$$

and the other attractive toward S and equal to

$$\frac{\mu}{S P^2},$$

the resultant force is, at every position of the particle, directed along the tangent to the curve.

N. B.—This curve is called the "Magnetic Curve," being one of those in which small iron filings would arrange themselves under the influence of a fixed magnet whose poles are N and S.

It is to be observed that each little piece of iron is a magnet, having two poles at its extremities, and that it must therefore set at the point, P, where it is placed, in the direction of the resultant force on either of its poles."

To construct the resultant of the forces $N\ P$ and $N\ S$ acting at the point P on the curve $P\ S$, we take:

The force in the direction of $N\ P = P\ Q$

The force in the direction of $P\ S = P\ T$,

*Fig. 36 in the text. The accompanying figure is a modification of *Fig. 36*.

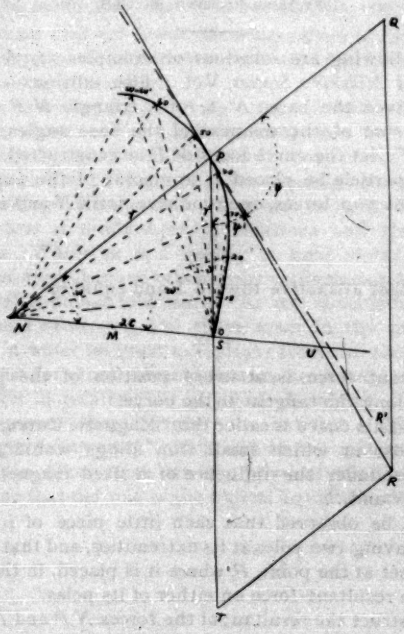
†The sum of the cosines is represented by

$$\cos \omega' + \cos \omega' = k$$

and, therefore, by the conditions of the problem,

$$PQ = \frac{\mu}{NP^2}, \; PT = \frac{\mu}{SP^2}$$

Take a line of any assumed length and in this case this length;



A B

which we assume equal to $\mu^{\frac{1}{3}}$. Find the length of a line, l, a fourth proprotional by construction from the proportion,

$$\frac{l}{\mu^{\frac{1}{3}}} = \frac{\mu^{\frac{1}{3}}}{NP}$$

From which

$$l = \frac{\mu^{\frac{1}{3}}}{N P}$$

Taking l as a known term of a second construction by means of a fourth proportional, we have

$$\frac{P Q}{l} = \frac{\mu^{\frac{1}{3}}}{N P}$$

or, substituting the value of l

$$P Q = l \frac{\mu^{\frac{1}{3}}}{N P} = \frac{\mu}{N P^2}$$

In the same manner we find

$$P T = l' \frac{\mu^{\frac{1}{3}}}{S P} = \frac{\mu}{S P^2}$$

Take $Q P R = \varphi$ and $T P R = \varphi'$

and $N P = r$ and $S P = r'$

In the triangle $P Q R$ we have

$$\frac{P Q}{Q R} = \frac{\sin P R Q}{\sin Q P R}$$

and since $Q R = P T$ and $P R Q = T P R$

the above becomes

$$\frac{P Q}{P T} = \frac{\sin T P R}{\sin Q P R} = \frac{\sin \varphi'}{\sin \varphi}$$

Also

$$\frac{P Q}{P T} = \frac{\frac{\mu}{N P^2}}{\frac{\mu}{S P^2}} = \frac{S P^2}{N P^2} = \frac{r'^2}{r^2}$$

from which it follows that

$$\frac{\sin \varphi'}{\sin \psi} = \frac{r'^2}{r^2}$$

Also,

$$\varphi' + \varphi = Q P T$$

These give two equations to determine φ' and φ.

Again:

$$\cos \omega + \cos \omega' = k$$

Differentiating

$$-\sin \omega - \sin \omega' \frac{d \omega'}{d \omega} = o$$

or

$$\frac{d \omega'}{d \omega} = -\frac{\sin \omega}{\sin \omega'}$$

From the triangle $N S P$

$$\frac{\sin SNP}{\sin NSP} = \frac{S P}{N P} \text{ or } \frac{\sin \omega}{\sin' \omega} = \frac{r'}{r}$$

therefore,

$$\frac{d \omega'}{d \omega} = -\frac{r'}{r}$$

Assume that $P R'$ is a tangent, and that

$$N P R' = \varphi_1' \text{ and } Q P R' = \varphi_1$$

and it follows that from calculus,

$$\sin \varphi' = \frac{r \, d \, \omega}{d s} \text{ and } \sin \varphi_1' = \frac{r \, d \, (\pi - \omega')}{d s} = -\frac{r \, d \, \omega'}{d s}$$

and hence

$$\frac{\sin \varphi_1'}{\sin \varphi_1} = \frac{\frac{r' \, d \, \omega'}{d s}}{\frac{r \, d \, \omega}{d s}} = -\frac{r' \, d \, \omega}{r \, a \, \omega}$$

Substituting the value of

$$\frac{d \omega'}{d \omega},$$

we have

$$\frac{\sin \varphi_1'}{\sin \varphi_1} = \frac{r'^2}{r^2}$$

Also,

$$\varphi_1' + \varphi_1 = Q P T$$

These also give two equations to determine φ_1' and φ_1.

But these two equations for φ' and φ_1' are identical with those for φ and φ', hence

$$\varphi = \varphi_1 \text{ and } \varphi' = \varphi_1'$$

and $P R'$ is identical with $P R$.

That is, the resultant of the two forces $N P$ and $S P$ is tangent to the curve at P, which was to be proved.

"38. Prove that the line of action of the resultant force of a magnet on a magnetic pole at P divides $N S$ externally in the ratio $N P^3 : S P^3$."

In the triangle $P N U$

$$\frac{\sin N U R}{\sin N P U} = \frac{N P}{N U}$$

and in the triangle $P S U$

$$\frac{\sin S U P}{\sin S P U} = \frac{S P}{S U}$$

From these equations we have

$$\sin N U P = \sin N P U \cdot \frac{N P}{N U}, \sin S U P = \sin S P U \cdot \frac{S P}{S U}$$

Now, since the angles

$$N U P = S U P$$

$$\sin S P U \cdot \frac{S P}{S U} = \sin N P U \cdot \frac{N P}{N U}$$

and, hence

$$\frac{N U}{S U} = \frac{N P \sin N P U}{S P \sin S P U}$$

But

$$\frac{\sin N P U}{\sin S P U} = \frac{\sin Q P R}{\sin T P R} = \frac{P T}{P Q} = \frac{N P^2}{S P^2}$$

Substituting this value in the above, we have

$$\frac{N U}{S U} = \frac{N P}{S P} \cdot \frac{N P^2}{S P^2} = \frac{N P^3}{S P^3}$$

which was to be proved.

"39. Iron filings are sprinkled over a sheet of paper on which a magnet rests; prove that all those filings which dip towards the same point on the line of the magnet lie on a circle (neglecting their mutual actions)."

If the filings dip towards the same point on the line of the magnet, the resultant force on the particle is directed along the tangent to the curve upon which the filings lie, and hence the tangents to the series of curves upon which these particles lie pass through a common point on the line of the magnet.

Let the point through which these lines pass be the point U. Now, we have just proved

$$\frac{NU}{SU} = \frac{NP^3}{SP^3}$$

and since U is a fixed point,

$$\frac{NP^3}{SP^3} = \text{a constant.}$$

or

$$\frac{r^3}{r'^3} = K^{\frac{3}{2}}$$

Taking the origin at the point M midway between N and S, and letting x and y be the coördinates of P, we have

$$r = \sqrt{y^2 + (c + x)^2} \quad , \quad r' = \sqrt{y^2 + (c - x)^2}$$

hence

$$\frac{\left\{ y^2 + (c + x)^2 \right\}^{\frac{3}{2}}}{\left\{ y^2 + (c - x)^2 \right\}^{\frac{3}{2}}} = K^{\frac{3}{2}}$$

or

$$\frac{y^2 + (c + x)^2}{y^2 + (c - x)^2} = K$$

From this, we have by reduction

$$y^2 + x^2 + 2c\frac{1 + K}{1 - K} + c^2 = 0$$

which is the equation of a circle.

AN INVESTIGATION OF THE COST OF POWER.*

By Clyde D. Gray.

PREFACE.

This investigation was undertaken in order to get a collection of reliable data on the production, cost and utilization of power by different methods. As far as the writer knows, there has been nothing published of this character and this attempt, although crude, may serve to give a slight insight into the subject.

In this investigation, complete files of the different engineering and technical periodicals were consulted as well as the transactions of the various engineering societies and the more important books relating to engineering in its many branches.

The writer has attempted to get the results of such tests and estimates as seemed reliable, to incorporate in the various tables given and has not tried to deduce any very specific conclusions, believing that the reader can best arrive at them in regard to any special case much better than if they were given by the writer. Such deductions as are given are, consequently, of the very broadest character.

The subject is a very broad one and the time given to it permitted only a brief review of the material that might have been used.

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When reference to any of the above periodicals is made in the body of the thesis, the initials of the periodical only are given and the volume and page on which it is found, thus: S.R.J. 1^{3}, 353, would be the *Street Railway Journal*, Vol. XIII, page 353. When the volume and page are not given, it is usually stated in what year and month the article referred to is found.

MAN POWER.

The power exerted by a man is variable and depends upon the individual to a large extent. His endurance and habits of life enter into the matter as well as the climatic and other conditions surrounding him. On account of all these variable factors, it is difficult to get a very close estimate of the power which he is able to produce.

In the *Trans. A.S.M.E.*, vol. VIII, p. 714, Dr. Thurston says that, on the average, a man exerts about ·1 horse-power. Rankine in his book, "The Steam Engine," p. 84–86, gives the power of a man on a crank as ·1 that of a horse on a cart, or ·125 that of the same horse working on a gin. In the discussion of the above paper, Mr. O'Neill mentioned a case of a man doing ·75 horse-power on a crank for short periods of time.

An abstract from the *Sci. Am.* in "Eng. News" for May 2, 1885, gives some figures on the power exerted by old men ascending stairs. One, 63 years old, exerted ·353 horse-power. Another of the same age produced ·231 horse-power. A third, 69 years of age, used ·276 horse-power, while a fourth, 72 years old, exerted ·222 horse-power.

In "The Animal as a Machine," Dr. Thurston gives the thermo-dynamic efficiency of a man as 20 per cent., which is about the same as that of the best steam engine. In respect to weight per horse-power, a man has 600–700 pounds as compared with the 1500–2000 pounds of the horse, or the 50–100 pounds of the bird. Mr. Box gives the power of a man, working ten hours per day on a winch, as ·072 horse-power, on a treadmill as ·105 horse-power and on a capstan, ·084 horse-power. If the hours of labor are reduced from 10 to 4 per day, then in the above cases the power will be increased to ·113, ·167 and ·134 horse-power respectively, thus showing the large increase of power as the time of labor is shortened. Mr. D. K. Clark says that the average man working on a pump, winch, or crane, exerts about ·1 horse-power if the day consists of ten hours, but that he can produce four or five times this amount if the time is shortened.

Rankine gives the following table for the power of a man doing different kinds of work:

	Hours Per Day.	Horse-Power.
Raising his own weight up stair or ladder	8	·1320
Hauling up weights with rope, lowering it empty	6	·0545
Lifting weights by hand	6	·0440
Carrying weights up stairs, returning unloaded	6	·0337
Shoveling earth to height of 5 feet 6 inches	10	·0142
Pushing or pulling horizontally	8	·0965
Turning a crank or winch	8	·0820
Working a pump	10	·0600

Assuming ·1 horse-power as the power of the average man, then, if labor can be procured for $1 per day of ten hours, a horse-power hour will cost $1; a horse-power year, assuming 3,000 hours per year, will cost $3,000, which is greatly in excess of any other kind of power. Another disadvantage of human power is that it cannot be worked continuously, but must have long periods for rest and recuperation. It also requires a large amount of space for a small amount of power as compared with other sources of power.

The absurdity of using man-power in place of steam or other similar sources may be shown by the following figures: Consider that 50,000 horse-power are needed for any purpose. If men are to be used, there will have to be three shifts, each working for eight hours per day and if each man can exert ·1 horse-power, it will require 50,000 x 10 x 3, or 1,500,000 men, or the equivalent of the population of a large city to produce the same amount of power as one plant. Consequently this kind of power is limited to purposes in which the use of the mind as well as that of the body is required and for such other purposes as can best be accomplished by its use regardless of cost.

ANIMAL POWER.

In the preceding chapter on human power, it was seen that man has certain limitations in regard to length of time in which he can work, etc. These apply equally well to the case of animals.

Mr. Box, in a table found in Thurston's "The Animal as

a Machine," p. 52, gives as the power of a horse working ten hours a day on a capstan ·477 horse-power, that of a mule, ·315 horse-power, of an ox, ·423 horse-power and that of an ass, ·131 horse-power, while if the hours of work are reduced to four per day, the power would be raised to ·75, ·501, ·669 and ·184 horse-power respectively.

Rankine gives as the work of a horse:

	Hours Per Day.	Horse-Power.
Cantering or trotting on light railway car	4	·815
Drawing cart or boat (walking)	8	·785
Drawing gin or mill (walking)	8	·546
Drawing gin or mill (trotting)	4·5	·780
Average		·785

The following table has been compiled from figures of Rankine and Box. Those of Box, from the section above and the others from Kent's Handbook, p. 435. The values are given in horse-power and also in percentages of the power of the average draught-horse.

	Rankine.		Box.	
Animal.	Horse-Power.	Per Cent.	Horse-Power.	Per Cent.
Horse	·785	100·0	·477	100·0
Ox	·660	84·1	·423	88·6
Mule	·500	63·7	·315	66·1
Ass	·250	31·9	·131	27·5

It seems from the above values that the horse-power as commonly used, 33,000 foot pounds per minute, is too large when compared with the actual work of the average horse; but it serves its purpose as a means of comparison of the values of different kinds of power just as well as though it were correct.

The cost of a horse-power year will be approximately as follows for a year of 3,000 hours:

Cost of horse	$150.00
Cost of harness	20.00
Total investment	$170.00
Interest, 5 per cent. Depreciation, etc., 15 per cent. Total 20 per cent.	$34.00
Feed and stabling, $0.25 per day for 300 days	75.00
Driver for two horses, at $1.50 (·5 x 1·50 x 300)	225.00
Total yearly expense	$334.00
Cost of 1 horse-power year, assuming horse, ·75 horse-power,	$446.00

The above estimate is very conservative and does not include charges and repairs on wagons, or insurance on horse and equipment.

In the *Transactions of the A.I.E.E.*, vol. XVI, p. 485, some figures are given by Messrs. Lever and Fleiss, comparing the cost of delivering goods in New York City by means of horses and electrically-driven wagons. They made a very careful series of tests of both methods and found that the cost per ton-mile of the motor-driven carriage was $0.0425 as against $0.102 for a two-horse heavy delivery wagon, thus making a saving for the motor of $0.0595 per ton-mile. The motor did the same amount of work in about two-thirds the time required by the horse.

The use of horses in traction work on street railways will be taken up later in comparison with other kinds of motive power.

WIND POWER.

The power of the wind can be easily and cheaply utilized for certain purposes, especially for the pumping of water and for such other uses where close regulation is not required. The greatest disadvantages of this kind of power are its irregularity and the difficulty of governing for a constant speed. The latter has prevented the extensive use of wind motors for electric lighting and the production of power to be transmitted electrically to machines. Nevertheless, by the use of storage batteries, these troubles have to a certain extent been eliminated, so that now it is perfectly feasible to do electric lighting and to furnish steady power for other purposes.

The power exerted by windmills depends upon the size of wheel, the velocity and regularity of the wind. The power of the best grade of mills is directly proportional to the square of the diameter and inversely as the revolutions per minute and increases directly as the square of the proportional velocity of the wind; *i. e.*, if the velocity is doubled the power is quadrupled. The modern mill of medium and large size will run in a 4-mile breeze, becoming very efficient in an 8 to 16-mile breeze and will run with safety up to a 45-mile gale. (Above taken from an article

in the *Iron Age*, based upon the observations of the U. S. Signal Service. See Kent, p. 497.)

Mr. A. R. Wolff in the *Trans. A.S.M.E.*, vol. III, p. 301, also given in Kent, p. 496, has a table concerning the power that is developed by different sizes of windmills and also the cost of power produced by them. The article in *Iron Age* mentioned above also gives some figures on the horse-power of wheels. The data are reproduced in the table below:

	D. H. P.			Cost.	Cost.	Gal. pumped 100 feet
Diam.	Wolff.	*Iron Age.*	Cost Mill.	H. P. hr.	H. P. yr.	per min.
10	·12	·15	175	$0.058	$169	4·75
16	·41		671	0.059	172	16·15
20	·78	1·00	993	0.045	131	31·25
25	1·34	1·75	1197	0·032	93	49·72
30		3·50				
40		7·50				
50		12·00				

The above is based upon a 16-mile wind for eight hours per day, which has been found from practice to be nearly correct.

The application of the windmill to electric lighting was tried by Mr. C. F. Brush, at Cleveland, O. and found to work very well. He used a storage battery of 408 cells, connected in 12 parallel-series having a constant capacity of 100 16-candle-power lamps. The mill was 56 feet in diameter and drove a dynamo at 500 revolutions per minute, having an output of 12 kilowatts at 70–75 volts, the regulation for charging the battery being automatic in its action.

Lieut. I. N. Lewis, in *Eng. Mag.* for December, 1894, describes a small lighting plant that was substituted for a steam plant and gives some figures in regard to the relative economy of the windmill when compared with the steam engine. These are given below:

	Steam.	Wind.
Number of lights	75	127
First cost	$1,000	$1,800
Depreciation	100	130
Interest	50	90
Operating expenses	100	10
Attendance	75	20
Total yearly cost	325	250
Cost per lamp year	4.33	2.00

It may be seen from the above figures that the cost of lighting by the use of wind power is less than one-half that by the use of steam.

Another method of storing energy produced by wind power would be to use the mill to pump water into an elevated tank from which it could be drawn and discharged through a water-wheel, preferably of the tangential type. The water-wheel could be belted to a dynamo or other machinery which it is desired to drive. This scheme seems very feasible, especially where water storage is needed for other purposes, as the mill could be set to run continually and keep the tank full. In this way, the tank would take the place of the storage battery and would need less repairs and attention as the complications, which would arise in the regulation for charging, would be absent. The capacity of the tank need not be so very large, one having a sufficient storage for twenty-four hours steady running of the plant being large enough for all practical purposes.

In order to make this plan clear, a hypothetical case is figured out below that will serve to show what might be done in this way. Suppose it was desired to light a private residence that had no means of getting electrical power from city or town mains and there was no water power available for the work, but enough water for its utilization in the tank-storage plan. There would be left steam, gas or wind power, any one of which might be used for the purpose. The steam and gas engine would probably give about the same results and the cost would be approximately the same unless steam was needed for heating or other purposes about the place. In the latter case, the steam would be the cheaper to use, for the same boiler could be used for both purposes; but on the other hand, the gas engine would need scarcely any attention while running and so it is likely that the cost of steam and gas power would about balance. From the comparison of costs in Mr. Lewis' paper, it is evident that the windmill is much the cheaper source of power for this use.

Suppose that about 75 16-candle-power lights are to be the maximum load. Then a 4-kilowatt dynamo would be

large enough to furnish current for them. Assuming 80 per cent. efficiency of the dynamo, the power needed at the pulley would be $4 \div 8 \times .746$, or 6·67 horse-power, or say 7 horse-power at the water-wheel, which would be ample to cover all loss in the belt. If the efficiency of the water-wheel is 75 per cent., which is a very conservative figure for wheels of this class, the power in the water at the jet must be about 9·5 horse-power, or 9·5 x 33,000 or 314,000 feet pounds per minute, and if the tank is elevated so as to give an effective head of 100 feet, it would need 3,140 pounds of water per minute to furnish the power. Allowing for the friction in the pipes, a 10-horse-power mill would probably be large enough to furnish the wheel with water continuously.

It is probable that not more than one-half of the lamps will be turned on at any time and then they will be used not over four hours per day, on the average. In this case, since the efficiency falls off with the load, the power needed at the jet will be 6 horse-power, or 1,980 pounds of water per minute, and in four hours, 1,980 x 4 x 60, or 4,750,000 pounds of water per day that would have to be pumped into the tank. From the table it is found that a 30-foot wheel will develop 3·5 horse-power with a 16-mile wind, on an average of eight hours per day and hence it would pump $(3{\cdot}5 \times 33{,}000 \times 60 \times 8) \div 100$ or 554,000 pounds into the tank which is more than needed to supply the forty lamps for four hours per day. The tank should be large enough to hold water for two or three days' run as the wind is a very uncertain means of power. In case it should be desirable to always have power it might be advisable to have a small gas engine that could be used in case of a long interval of calm weather.

The cost of installing such a plant and the fixed and operating expenses are hard to estimate; but an attempt has been made in the following calculations:

Cost of mill, tower and pump	$1,500
Cost of tank, dynamo and wheel	900
Cost of piping	100
Total cost of plant	$2,500

Interest at 5 per cent. on $2,500	$125
Depreciation on mill at 5 per cent.	75
Depreciation on tank and machinery	50
Attendance and operating expenses	50
Total yearly cost	$300
And on the basis of 6 horse-power a horse-power year would cost,	$50
or for seventy-five lamps, a lamp year would cost	4

This estimate is very conservative and the costs could probably be reduced 50 per cent. in some cases. The item of cost of tank would be reduced if the water from it were used for other purposes, also if it could be built on a hill so that it would not have to be raised on a tower for the sake of getting the head. For small work, the tank and mill could be supported on the same tower, thus saving in first cost. The item of attendance could be reduced to a very small amount if the plant were close to the house, so that one of the men employed about the house or barn could look after it. If it were situated in a section of country where the water was used for irrigating purposes, the water, after passing the wheel, could be used in the usual manner for irrigation.

WATER POWER.

Water is a very cheap and easily controlled means of producing power, especially in sections of country where it is available and where coal is high in price, so that it pays to transmit power electrically to great distances.

There are two classes into which water-power can be divided: One where a large quantity of water is available, but having a small head, the other, in which a small amount of water is at hand, but with a considerable head. The first applies to the eastern part of the United States in general, while the other is used more in the mountainous sections of the West, where fuel is expensive. Thus the turbine class of water-wheels is more generally used in the East and the tangential or impulse type in the West.

Some of the more important water-power plants in this country are given in the table following:

TURBINE WHEELS.

	Horse-Power.	Head Ft.	Kind of Wheel.
Butte, Mon.	4,000	58	Leffel, Niagara type.
St. Croix, Wis.	4,000	82	Victor horizontal.
Stuyvesant Falls, N. Y.	3,300	40	Victor.
Montmorency, Can.	5,000	260	Victor high pressure.
Hartford, Conn.	3,000	29	Horizontal.
Niagara, N. Y.	50,000	180	Vertical.

IN PROCESS OF CONSTRUCTION.

	Horse-Power.	Head Ft.	Kind of Wheel.
Richmond, Va.	11,000		
Shawanigan, Can.	75,000		
Sault Ste Marie	50,000	17	Horizontal type.
Messena, N. Y.	75,000	35'5	Victor horizontal type.

TANGENTIAL WHEELS.

	Horse-Power.	Head. Ft.	Kind of Wheel.
Big Cottonwood	2,400	370	Pelton, 61-inch.
Ogden, Utah	5,000	450	Knight.
Utah Station of Utah Co.,	2,000	450	Pelton.
Blue Lakes	2,700	1,040	Doble.
San Bernardino, Cal.	4,000	700	Pelton, 82-inch.
Snoqualmie Falls, Wash.,	8,000	270	Doble.
Colgate, Cal.	15,000	700	Risdon.

The above tables may serve to show to what an extent water-power is being used in this country. It is especially useful where the power can be transmitted to mines or for other power purposes in sections of the country where coal and transportation charges are high. In the East, the water-powers are being developed for manufacturing and electrolytic purposes, because they are cheaper and cleaner than steam power. Another reason may be that a large amount of power can be produced in a single plant, as at Niagara Falls, and transmitted many miles for application in neighboring cities.

The old forms of over-shot, under-shot and breast wheels are not used to any great extent at the present time as their efficiencies are low when compared with the two types of modern wheels universally in use to-day. Mr. A. F. Guy, in his book "Electric Light and Power," gives the efficiency of over-shot wheels from 50 to 70 per cent., breast wheels from 45 to 50 per cent. and under-shot, from 27 to 30 per cent. Emerson says that over-shot wheels have been known

to give 75 per cent. efficiency, but the average performance is not over 60 per cent. (Kent, p. 596.)

In regard to the tangential class of wheels, some tests have been made upon them and the principal results are given in the table below:

TANGENTIAL WHEEL TESTS.

Kind.	Size. Inch.	Horse-Power.	Head. Feet.	Efficiency. Per Cent.	Authority.
Pelton . .	60	107·0	384·7	87·30	Browne, *Eng. News*, F. '92.
Pelton . .	12	1·9	230·0	80·00	
Cascade .	38	15·1	164·1	91·02	Cooper, F. In. v. 143-376.
Cascade .	26	9·5	163·4	91·85	
Cascade av.,	38	13·8	159·2	88·65	
Cascade av.,	26	14·8	164·7	88·28	

There has been a considerable amount of testing on small wheels of this type in the Sibley College laboratories and efficiencies ranging from 65 to 90 per cent. and over have been found, with the average about 80 per cent. It is safe to assume the efficiency of large wheels of this class, between 85 and 90 per cent, and that of smaller wheels between 75 and 85 per cent.

The turbine class of wheel is of the greatest importance in this section of the country and a table of tests is given below, embodying some of the most extensive and carefully conducted tests that have ever been made, the Centennial tests of 1876 and some made at Holyoke, Mass., at which place there is a special laboratory for such work.

TURBINE TESTS.

Wheel.	Efficiency. Per Cent. Full.	Three-fourths.	One-half.	Authority.
Risdon	87·68	82·41	75·35	Centennial tests, Kent, p. 596.
National . . .	83·79	70·79		
Geyelin . . .	83·30			
Tait	82·13	70·40		
Goldie & McC.,	81·21	55·90		
Hunt Mch. Co.,	78·70	68·6		
Tyler	79·59	79·92	69·59	
Geyelin . . .	77·57			
Knowlton . .	77·43			
Cope & Sons .	76·94			
Barber & H. .	76·16		71·14	
York Mfg. Co.,	75·70	67·57		
Mosser & Co. .	75·15	70·52	66·04	

Wheel.	Efficiency. Per Cent. Full.	Three-fourths.	One-half.	Authority.
Sampson, 45″ .	82·03	83·68	75·95	Leffel catalogue. Test in 1897.
Sampson, 35″ .	81·04	83·88	76·19	
Boyden, 81″ .	79·37	76·18	64·90	Thurston, A.S.M.E, 8–359.
Hercules . . .	80·50	73·78		Holyoke tests.
New American,	79·50	73·20		These figures for full load and for three-fourths load are averages from three-fourths to full and from one-half to three-fourths.
Success	78·60	70·80		
Tyler	76·60	65·50		
Tait	74·40	68·00		
Thompson . .	72·10	69·60		
Nonesuch . .	71·20	61·90		
Houston . . .	71·70	39·70		
Burnham, 36″,	81·82	70·78	75·26	
Hercules, 45″,	80·70		74·40	Aldrich, A.S.M.E., 15–705.
Collins	83·50			S. Webber, *Eng. Mag.* 1–335.
Fourneyron .	72·50			
Boyden	78·00			
Howd	79·00			Same. Francis' test in '51.
Swain	84·00			Same. Francis' test in '59.
Collins, 60″ . .	79·70	78·70	65·20	Bodmer in "Hydraulic Motors, Turbines and Pressure-Engines," p. 387.
Collins, 60″ . .	83·78	with draft-tube and cone.		
Collins, 60″ . .	84·34	with tube alone.		
Boyden	80·17			
Hercules . . .	85·80	87·00		
Collins	85·06	83·27	74·64	
Victor	85·98	76·00		Holyoke test in 1895.

From the above table, it may be seen that there is a considerable variation in the efficiencies of turbine water-wheels. 87·68 per cent. is the highest in the list, but there is room for doubt in this case, as there are no records of more recent tests that show over 86 per cent., while there are many that show from 85 to 86 per cent. Kent says that the limit of turbine efficiency is about 86 per cent. and that 75–80 per cent. is very good. (Kent, p. 594.) Emerson says that in tests made at the Philadelphia water-works in 1859–60, on eighteen wheels, one gave less than 50 per cent., two between 50 per cent. and 60 per cent., six between 60 per cent. and 70 per cent., several between 71 per cent. and 77 per cent., two 82 per cent. and one 87·77 per cent. The last figure is rather high and may be doubted. Weisbach says that the limit of efficiency is 88 per cent.

It is safe to take the efficiency of good modern wheels at

from 80 per cent. to 85 per cent., under any head for which they are designed. There are several American manufacturers of turbines who will guarantee an efficiency of 80 per cent. from three-fourths to full load, and in some cases as high as 85 per cent. In general, the efficiency does not fall off a great deal for three-fourths load and in some cases of modern wheels it is higher at three-fourths than at full load.

The costs of water-power plants are widely different, depending upon the location, size and extent of the hydraulic works needed, length of penstock and flume and many other things that differ in the various localities. Below are given some figures in regard to the costs of plants. These are low-head plants fitted with turbine wheels and are used principally for mill or factory purposes. The costs do not include costs of dam unless so specified, but include everything else in the plant. The horse-power basis upon which they are figured is the horse-power delivered at the wheel shaft.

WATER-PLANT COSTS.

Place.	Cost per D. H. P.	Authority.
Lawrence, Mass.	$68 67	Manning, A.S.M.E., vol. 10–499.
Manchester, N. H.	66 00	
Lowell, Mass., 13 feet head	110 00	C. T. Main, A.S.M.E., vol. 11–108.
Lowell, Mass., 18 feet head	57 00	
Lawrence, Mass.	63 00	
Lawrence, Mass., 1,000 H. P.,	67 50	
Concord, N. H. (with dam)	57 75	Webber, A.S.M.E., 17–41.
Augusta, Ga.	34 20	
Columbia, S. C.	37 50	
Caratonk Falls, Me. (dam)	24 00	
Omaha, Neb. (estimate)	67 33	*Eng. Mag.*, vol. VII, p. 409.
Zurich (with dam)	100 00	*Eng. Mag.*, February, 1900.
Paderna, Italy (with dam)	120 00	
Big Cottonwood, 3,000 H. P.	108 25	*Eng. News*, October 1, 1896.
Average without dam	53 41	(Excluding Lowell, $110.)
Average with dam	79 55	

It is probable that the cost of such plants will be from $40 to $60 excluding the cost of dam, but including all other parts and when the dam is included that it will be from $60 to $100. Webber, in *Iron Age*, February and

March, 1893, says that water-power plants can be put in for $100 per horse-power and Stilwell, in A.I.E.E., 10–484, says that the cost may be as low as $65.

The cost of water-power per horse-power year is variable, depending, as it does, upon the first cost of plant and hence no very good average can be found. The table given below may serve to show the costs in some cases that have been reported.

COST OF WATER-POWER.

Place.	Cost per H. P. Yr.	Authority.
Lawrence, Mass.	$13 70	C. T. Main, A.S.M.E., 13–140.
Canada (lowest)	6 25	Meyer, *Sci. Am.*, February 9, 1882.
Cottonwood	16 10	*Eng. News*, October 1, 1896.
Lawrence, Mass., 1,000 H. P.,	22 62	Manning, A.S.M.E., 10–48.
Lawrence, Mass., 500 H. P.	19 13	Main, A.S.M.E., 13–140.
Concord, N. H.	8 64	Webber, A.S.M.E., 17–41.
Augusta, Ga.	11 05	
Columbia, S. C.	9 50	
Omaha, Neb. (estimate)	8 08	*Eng. Mag.*, vol. VII, p. 409.
Norway (electrolytic work)	11 25	*Chem. Ind.*, vol. XXIII, p. 121.
Niagara (sold for)	13 00	Emery, A.I.E.E., 12–358.
Estimate on plant	5 42	Webber, W. O. *Eng. Mag.*, 15–926.
Average of the above	10 72	

From the above table it may be seen that the cost per horse-power year is $10.72. Webber gives it as $10 to $12. (*Iron Age*, February and March, 1893) and Conant, in an article in the *Street Railway Journal* for October, 1898, gives the cost as ranging from $10.40 to $22.40. A fair average may be taken as varying from $10 to $15.

Water-power has its disadvantages as have other kinds of power, and among them may be mentioned the effect of drouth, unless there is a very large storage capacity for water, which, if it is provided, greatly increases the first cost so that it is often cheaper to install steam-power to be used in emergencies of this kind. Another great disadvantage, which is being overcome rapidly since the use of water-power has taken such rapid advances in the last few years, is the difficulty of governing the speed of the wheels. A few years ago it was impossible to use turbines on any kind of work that required reasonably good regulation for

a constant speed and the question of using them to drive electrical machinery was scarcely thought of; but now they may be regulated so as to give fairly good regulation even for such exacting service as electric lighting and the running of alternators in parallel. In some sections of the country where there have been good water-power plants, the water is failing on account of the cutting down of the forests on the section of country dependent upon for supply. This will have to be met by the increased amount of storage needed to carry the plant over the dry seasons, which may be so expensive to build that the plants may be abandoned, or else steam or other power put in as an auxiliary. This question of gradually failing water supply should be carefully looked into before any large investment in a water-power plant is made.

The cost of attendance of water-power plants is less than that of steam or other plants and, on account of the absence of a fuel bill, the operating expense is very small; but on the other hand the first cost is large and therefore the fixed charges are correspondingly greater than with other kinds of plants. The depreciation and repair bill is less than the case of steam, an allowance of 4 per cent. usually being considered ample to cover these items, while the corresponding allowance for a steam or gas engine plant is 10 per cent. to 15 per cent.

STEAM POWER.

Perhaps the best-known and most extensively used source of power is the steam engine, which has come into use almost entirely within the past century. From the humble beginnings of Newcomen and Watt have developed the great engines of Corliss, Leavitt, Reynolds, Nordberg and many others of the same class. This development was necessarily slow and was a gradual refinement and perfecting of details until the present almost perfect type of engine was evolved. It is a question whether the present type of steam-engine will be improved very much in the future. If so, the advance will be along the line of the employment of higher steam-pressures together with the

use of superheated steam. The tendency is in this direction at the present time and it is possible that by such methods, with a further use of the steam turbine for certain purposes, the efficiency of the steam engine may be slightly increased.

It may be assumed for all practical, purposes in which a reasonable amount of safety for persons and property is desired, that the existing range of pressure and hence the limit of efficiency, which is very closely dependent upon the pressure, has been reached in the average case. This being the case, the limits of the use of the steam engine and the cost of its operation for different purposes are well known and the cost of operation and maintenance can be estimated very closely from the results of tests and other data that has been made public.

As the steam engine depends upon the fuel which is used in the boiler furnace for its working substance, it is fitting that a little space should be given to the various kinds of fuel in use under boilers, considering their relative values as steam producers and the cost of power as modified by the item of expense of fuel. Coal is the fuel used to the greatest extent for this purpose, although wood, peat, oil, straw, sawdust and other materials are used in limited amount.

The table below contains the calorific values of coals from different sections of the country.

CALORIFIC POWER OF COAL.

Locality and Kind.	B. T. U. per lb.	Authority.
Colorado, all kinds, 6 samples	14,500	Poole, "Calorific Power of Fuel."
Illinois, all kinds, 51 samples	13,300	
Indiana, all kinds, 6 samples	14,160	
Maryland, all kinds, 1 sample	13,438	
Ohio, all kinds, 17 samples	14,392	
Pennsylvania, anth., 21 samples	14,110	
Pennsylvania, bit., 28 samples	14 951	
W. Va., Pocahontas, semi-bit.	15,739	
W. Va,, average, all kinds	13,000	
American anthracite, average	14,833	Thurston, "Steam Boiler," p. 195.
American bituminous, average	14,796	
Anthracite, average	14,400	Morin and Tresca.
Bituminous, average	13,500	

Locality and Kind.	B. T. U. per lb.	Authority.
Cumberland, Md., George's Crk.	15,141 14,085	
Pocahontas, Va., 5 tests	15,086 14,507	
New River, Va., 6 tests	14,696 14,427	Barrus, A.S.M.E., 14–816.
Youghiogheny, Pa., lump	13,752	
Youghiogheny, Pa., slack	12,988	
Anthracite, 11 tests	14,509 12,873	
Anthracite	14,446	Average of Poole, Thurston, Morin and Tresca.
Bituminous	14,873	Av. of Poole and Thurston.

By the inspection of the above table it is seen that the bituminous coal is slightly the better of the two classes on the average. The values differ greatly with the locality, but samples from the same place do not differ greatly and hence one can tell approximately the value if he knows from where it came. For further information in regard to coal see Kent and also Poole's "Calorific Power of Fuel."

If the chemical analysis of a sample of coal is known, it is easy to calculate its heating value from the formula of Dulong:

$$\text{Heating power in B.T.U.} = 14{,}500\,C + 62{,}500\left(H - \frac{O}{8}\right)$$

in which C, H and O are the proportions of carbon, hydrogen and oxygen in the coal. The results given by this formula are very near the values found by calorimetric tests as shown by the work of Mahler. (*Mineral Industry*, vol. I, p. 97.)

Kent has made up a table based upon the results of Mahler's tests, from which the value of any coal can be calculated to within 3 per cent., if the proximate analysis of the coal be known. This table is given in his handbook, p. 634.

Oil is the fuel that is perhaps used to the greatest extent after coal, and a few values are given in the table:

OIL VALUES.

Kind and Locality.	B.T.U. per lb.	Authority.
Heavy petroleum, W. Va.	18,324	Poole.
" " Pa.	19,210	"

Kind and Locality.	B. T. U. per lb.	Authority.
Heavy Petroleum, Pa.	20,736	Poole.
" " W. Va.	18,200	Thurston, "Steam Boiler," 180.
Light " "	18,400	Poole.
" " Pa.	17,930	"
" " W. Va.	18,350	Thurston,
" " Pa.	18,050	"
Heavy " Ohio	18,718	Poole, "Cal. Power of Fuel."
" " "	18,450	Thurston,
" oil, Pa.	19,244	Poole.
" " W. Va.	18,184	"
Petroleum, Pa.	20,360	Thurston,
" "	20,746	Barr, "Combustion of Coal."
" refuse	19,832	Favre and Silbermann.
Heavy crude oil, Pa.	20,736	" " "
Wyoming, average	19,400	Poole.
Europe	18,000	Thurston.

From the above, the value of heavy Pennsylvania petroleum may be taken as about 20,000 B.T.U. per pound and that of the light as 18,000 B.T.U. per pound, while the Ohio oils are about 18,500 B T.U. per pound in value and those from West Virginia have a heating value of about 18,300 B.T.U. It is safe to assume that the average heating value of American oils is in the neighborhood of 18,500 B.T.U. per pound.

[*To be continued.*]

STORING PETROLEUM UNDERGROUND.

Apropos to the extended discussion growing out of the late very destructive petroleum tank fire at Point Breeze, Philadelphia, the following item concerning the dangers arising from storing petroleum in underground tanks appears to be important:

A firm in the London suburbs had twenty-five of these underground tanks filled with petroleum. The system of discharging water through five separate intercepting chambers was conceded to thoroughly extract all but the smallest portion of the spirit. A heavy storm broke over the district during the afternoon, and the sewers failed to cope with the heavy rush of storm water. Consequently a large amount of water found its way to these tanks and washed away from three of them the puddling clay with which they were sealed. A large quantity of spirit was thus liberated. The storm was followed by a fire in the vicinity of the petroleum tanks, and while the firemen were engaged in its subjugation the petroleum flowing through the streets with the superfluous water exploded with terrific violence. Four persons lost their lives and several were injured. Fortunately the concussion did not disturb the other tanks, otherwise an appalling catastrophe would have ensued. W.

ELECTROLYTIC SODA AND BLEACH.

The Hargreaves-Bird process for producing soda and bleach electrolytically is now in operation on a commercial scale at Middlewich, in Cheshire, England, and the products are finding a ready market. At the present time fifty cells, of the type described in the *Mineral Industry*, vol. VI, are at work, and the daily capacity is about nine tons of bleach and thirteen tons of soda crystals, though the soda output is not marketed solely as crystals. Another set of fifty cells is in course of erection, and further extensions will be proceeded with as the products become known. The Electrolytic Alkali Company has always exhibited caution in conducting its business, and its policy has been to refrain from suddenly increasing the supply of these products. Thus it does not upset the chemical market nor make violent fluctuations in the price.

An incidental advantage of this process is that the bleach obtained keeps absolutely dry. There is no hydrochloric acid about to form calcium chloride, which is always found in Leblanc bleach. Another point of interest is that the soda crystals average 99 per cent. in purity, the remaining 1 per cent. consisting of sodium chloride, sulphate and sulphite of soda. This small proportion of sulphate and sulphite is due to the presence of sulphur in the carbonating gases. Brunner, Mond & Co., who use the ammonia-soda process have recently pointed out that there is a good deal of soda placed on the English market by English and Continental producers that contains over 25 per cent. of sulphate of soda and in some cases even a greater percentage than that. These crystals are presumably made by the Leblanc process, and the black ash process must be imperfectly carried out with a view of lowering the cost of production. Brunner, Mond & Co. claim a percentage of 98·25 for their soda crystals, not quite so high as the figure given by the Electrolytic Alkali Company, but still high enough for all purposes for which soda crystals are used.—*Engineering and Mining Journal.*

LANTERN SLIDES SHOWING STEREOSCOPIC RELIEF.

The desirability of making lantern-slide projections—landscapes, buildings, portraits, etc., so as to give the effect of natural relief, is universally admitted, but thus far no single method of accomplishing the object has been suggested. The superposition of two pictures of the same subject on the slide, one outlined in red and the other in blue, which when projected on the screen are slightly "out of register," and which are examined through specially prepared spectacles of red and blue glass affords perhaps the simplest way of accomplishing the result, but the method is nevertheless complicated.

Another ingenious optical artifice for giving the stereoscopic effect with lantern projectors is the following: A slotted disc is rapidly rotated before two lanterns, by which the views are projected on the screen in rapid alternation. The observer looks at the pictures through other slots cut on the rim of the disc in such manner that the right eye sees only the picture from the lantern on the right and the left eye that projected by the left lantern. By this device, it is said, if the rotation of the disc be made sufficiently rapid, the stereoscopic effect is produced without any perceptible flickering. W.

THE WATERHOUSE-FORBES METHOD OF AND APPARATUS FOR STERILIZING AND HEATING LIQUIDS.

[*Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the invention of Addison G. Waterhouse and John S. Forbes. Sub-Committee: A. C. Abbott, Chairman; H. W. Spangler, H. R. Heyl, Philip Pistor, H. F. Keller.*]

HALL OF THE FRANKLIN INSTITUTE,
[No. 2171.] PHILADELPHIA, March 6, 1901.

The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of the Waterhouse-Forbes Method of and Apparatus for Sterilizing and Heating Fluids to Predetermined Temperatures, reports as follows:

The investigating committee has subjected the Waterhouse-Forbes method and apparatus for the sterilization of fluids to what it deems the necessary investigation and tests, and begs leave to submit the following report:

Letters patent for the apparatus were granted to Addison G. Waterhouse and John S. Forbes, on November 28, 1899 (No. 638,192), and again on August 7, 1900 (No. 655,665).

An examination of the apparatus shows it to consist of a metal chamber divided into two compartments by a deeply corrugated partition. Into the one of these chambers the fluid to be sterilized is allowed to flow until a certain fixed level is reached, when its further passage is impeded. At this point provision is made for heating to the boiling point or any other desired lower temperature a small volume of the fluid. By such heating ebullition results, and this, together with the necessary expansion in volume, carries the fluid over a weir into the other compartment of the apparatus at a temperature at or about its boiling point. As it passes by gravity into the second compartment, and flows over the deeply corrugated or fluted partition that separates it completely from the inflowing, unheated fluid,

its temperature is gradually reduced until it reaches the point of exit where it leaves the apparatus at a temperature of from 4 to 5° higher than that which it had on entering.

The important features of the apparatus are that it can operate successfully only through the agency of sufficient heat to cause the fluid to boil over the point at which the continuity of its flow is purposely broken, thereby certainly destroying the vitality of those disease-producing organisms

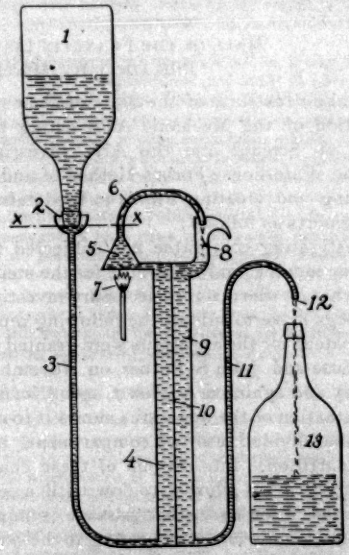


FIG. 8.

that are concerned in the causation of the common water-borne diseases, and that by the withdrawal of heat, the complete stoppage of the flow of water through the machine is brought about, thus preventing all possible contamination of the sterilized water by the inflowing unsterilized water. The principles involved and the mode of

operation of the apparatus are best understood by the accompanying diagram and more or less detailed description.

Fig. 1 is a purely diagramatic view of the ærostatic feed apparatus, and serves to explain the method of operation.

The raw or unsterilized water is supplied from the inverted bottle 1. The water runs from the bottle 1 into the cup 2, then down through the pipe 3 into the compartment 4 of the heat exchange, which it fills. When compartment 4 is filled, the water runs into the heater 5 and rises in the pipe 6 to the level *X*, where it stops. No more water will now run out of the bottle 1, because its mouth is sealed by the water in the cup 2 at the level *X*. The burner 7 is now lighted and heat is applied under the heater 5, which causes the water in the heater to boil, and in boiling it rises in the pipe 6 and flows over into cup 8, just as a pot on a cooking range will boil over. It is therefore impossible for any water to pass through the apparatus until it has boiled, for it is only by boiling that it can rise sufficiently in the pipe 6 to flow over into the cup 8. This boiling lasts for but the fraction of a second, and once the water has passed through the pipe 6 it is removed from where heat can again reach it. When some water has boiled over, as above stated, the level of the water in the heater 5 and likewise the level of that in the cup 2 is lowered. This exposes the mouth of the bottle 1, so that a small quantity of air enters the bottle and allows a corresponding quantity of water to run out of the bottle and refill the cup 2 and heater 5 up to the level *X* again, when the mouth of the bottle is again sealed by the water, and no more water can run out of it until the level is again lowered by reason of more water boiling over through the pipe 6.

This action becomes continuous, for the flame 7 is constantly boiling the water in the heater 5 and causing it to flow over through the pipe 6. The water continues to boil over into the cup 8 and quickly fills compartment 9 of the heat exchange. When compartment 9 is filled the water runs out of the pipe 11 at the opening 12 into the receiving

bottle 13. While passing down through the compartment 9 the heat of the water, which is boiling hot, is transferred, by conduction, through the thin metal partition or diaphragm 10 to the cold water passing up through compartment 4, so that the water which is boiled in the heater 5 passes out of the apparatus nearly as cold as that entering, while the cold water entering the apparatus becomes heated as it passes up through compartment 4, and reaches the heater 5 in a very hot condition and nearly at the boiling point.

Therefore, the only heat which has to be supplied to keep the apparatus running continuously, is that necessary to bring the already highly heated water entering the heater 5 to the boiling point, and cause it to rise above the normal water level *X* and boil over through the pipe 6, and so pass on through the remainder of the apparatus to the discharge outlet 12.

The committee has subjected the apparatus to such tests as it deemed necessary to determine its sanitary value as a sterilizer of purposely contaminated waters. As a result of these tests it was found that if water be purposely impregnated with very large numbers of living, non-spore bearing bacteria of known species, and then passed through the apparatus, these bacteria are all killed during the passage and the water leaves the apparatus sterile in so far as the species of bacteria used are concerned. Since it is in the non-spore forming group that the pathogenic species commonly carried by polluted waters belong, the sanitary importance of the apparatus is at once manifest.

When the more resistant spore-bearing varieties of bacteria were substituted, the results of this method of sterilization, though not so uniform as with the less resistant forms, were, however, sufficiently satisfactory to warrant the opinion that for all practical purposes the outflowing water was sterile.

The advantages of the apparatus may be briefly summarized as follows:

(1) In order for it to operate, all water passing through it must be brought to the boiling point.

(2) The time of boiling and the rapidity of cooling are so brief as to rob the water of but a part of its naturally contained gases.

(3) Living bacteria that are concerned in the causation of water-borne diseases are destroyed in passing through the apparatus.

(4) The action of the apparatus is automatic and it may be kept in continuous operation so long as the supply of raw water and a sufficient source of heat are available.

An objection that has been raised against the apparatus is that it does not clarify the water. This is true, but is of importance from the æsthetic standpoint only, and is moreover a defect that is easily remedied and one that in no wise lessens the sanitary value of the apparatus.

In view of the ingenuity displayed in the adaptation of fundamental physical principles; the fact that the apparatus as perfected is unique; that it is of extreme simplicity and with ordinary use is not liable to be disordered; and finally, its manifest sanitary value, the Franklin Institute awards to the inventors, Addison G. Waterhouse and John S. Forbes, of Philadelphia, Pa. the Elliott Cresson medal.

In reaching its conclusions, the committee has not only personally inspected the apparatus and subjected it to tests under its own supervision, but has also taken into account the elaborate report made upon the apparatus by the surgeon-general of the United States Army.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, May 1, 1901.

JOHN BIRKINBINE, *President.*
WM. H. WAHL, *Secretary.*

Countersigned by
LOUIS E. LEVY,
Chairman Committee on Science and the Arts.

CHARLES E. SMITH.

HIS RELATION TO THE AMERICAN IRON INDUSTRY.

By E. Alex. Scott.

The Franklin Institute, in its three-quarters of a century of active life, has numbered among its members many men whose names will remain inseparable from some of the most important inventions and discoveries of the nineteenth century. We, their successors, are proud of their achievements; but, in these later days of technical schools and industrial progress, we can have little conception of the difficulties under which they labored in working out the problems which they solved. Nor do we duly appreciate the tremendous influence which the Institute has exerted through all the period of its existence, during a large portion of which it was the chief, and almost the only source of technical information. How great that influence has been can never be known.

Charles E. Smith

Among those who have attained to eminence in particular industries or public station many were, in early life, constant attendants at the meetings of the Institute and drew inspiration from the bright intellects whose recorded thought is now a priceless heritage. Although they did not become prominent in the work of the Institute, they went into the world equipped with the knowledge which brought them fame and fortune.

Among these, the late Charles E. Smith, President of the Philadelphia & Reading Railroad Company, was a notable example. Mr. Smith is best known to the older members of the Institute and to the public generally as the capable engineer and financier under whose brilliant management

the Reading Railroad, a defaulting corporation, was brought up to a state of physicial efficiency and financial prosperity until then unexampled in the history of railroading. The golden age of that great property is spanned by the period of his presidency. His career as president, from 1861 to 1869, stamped him as a railroad manager of the first rank, a far-seeing financier of unflinching integrity, and as a patriot who fearlessly supported his government in the most critical period of its existence, with the very essential aid of the property under his control, while the most powerful interests conspired to defeat his purpose.

Few of the members, however, knew what Mr. Smith's relations were to the infant iron industry of this country, which has grown to such proportions that it has outranked every other, and has made America the first among nations. The history of the marvellous progress of metallurgical science can be read in the recorded transactions of the Institute, but it is fitting that a chapter should be added to show how the scattered energies and diverse methods of the early American workers in the art of iron manufacture were organized in the interest of scientific and financial success.

Born in Philadelphia on November 1, 1820, educated at West Town School and brought up in the principles and faith of the strictest sect of the Society of Friends, Charles E. Smith commenced the practical work of his life at the age of eighteen years as a member of an engineering corps, engaged in the laying out and construction of a railroad in Tioga County, Pa. When it was completed he was appointed Superintendent, and also had supervision over the Blossburg Coal Mines, whose product the road was built to transport. Thus, right at the beginning of his business career, he was called upon to assume the duties of administration, as well as the technical work of a civil and mining engineer. The six years spent in that region were valuable in experience. There he formed that habit of quick decision and prompt execution which characterized all his later business career. His orders were imperative and permitted neither of modification nor delay in their execution. This was the natural outcome of supreme authority en-

trusted to one so young, and his appointment at that age was an evidence of the recognition of his ability by those who placed him in that position.

He returned to Philadelphia in 1844 to seek a wider field for his energies. He had seen enough of the natural resources of the State to convince him that the iron industry must become an important one. Bar iron, rods and rails were then nearly all imported, and the transportation facilities were very meagre. After studying the subject for a year or two, he designed, and in 1846 built, the Fairmount Rolling Mill, whose site on the Schuylkill River above Fairmount Avenue, at the foot of Lemon Hill, is now occupied by the Lincoln Monument. The Reading Railroad on one side and the boats of the Schuylkill Navigation Company on the other gave ample facilities for the transportation of materials and products.

Mr. Smith's connection with the manufacture of iron extended over a period of about sixteen years, from 1845 to 1861, during the greater portion of which he managed his own plant. Among his contemporaries and associates during that period were Abram S. Hewitt, John Fritz, Coleman Sellers, James Moore and Washington L. Jones, to all of whom the writer is indebted for information as to Mr. Smith's enterprise and ability, and to the condition of the iron industry at that time.

Nearly every branch of the business was then in its formative stage. The processes for the reduction of the ores, the carbonization of the iron and manufacturing it into merchantable shapes were but crude imitations of foreign methods. Experience with American ores and fuels had not been sufficient to develop the character of the one or the value of the other, and American genius had not then set its stamp upon any of the improved machinery which has since become such an important factor in the economy of production. These gentlemen unite in saying that Mr. Smith was a remarkably energetic and progressive man, and was quick to recognize the value of any real improvement and adopt it in his business. Some of these improvements were first put to use in the works under his management.

The Fairmount mill was hardly in operation before he began to make improvements in it. The late James Moore, who was called in to make some changes in the rolls, said these improvements were radical, and were great advances in the art at that time. Among these was an arrangement to use the fire from the puddling furnaces to heat the water under the steam boilers, saving not only a great deal of coal which cost more then than now, but also the handling of it. The changes in the rolls were to ensure the rolling of rods and bars true to size. It is said that the Fairmount mill was the first in this country to roll rods that the locomotive builders would be satisfied with. More than a decade after this the number of mills in the country that could roll round or square iron true could be counted on the fingers of one hand.

In those days nearly all the rolling mills had puddling furnaces and prepared their own iron for the rolls. There was little knowledge of the character of the cast iron bought from various furnaces, and only an empirical knowledge of how to prepare it for the rolls.

The best practice was to depend upon the judgment of a foreign skilled laborer. The steam hammers of the period were lifted by a cam and descended by their own weight. The Nasmyth steam hammer had, in 1846, just been brought to notice in this country through the late Samuel Vaughn Merrick, and Mr. Smith was one of the first to appreciate its value and put it to use in his mill. In this he was opposed by his partners, but his will was law, and the hammer went in with excellent results.

The mill had been running less than a year when Congress repealed the Protective Tariff Act of 1842. Mr. Smith's opinion in favor of the protection of American industries had been formed while in charge of the Blossburg Coal Mines, which had been started into activity and made prosperous by the passage of the Act. Recalling the general business stagnation, and the idleness in mine and workshop which preceded its enactment, he prophesied disaster to the iron mills by its repeal, and at once sold out his interest to his partners, who were not of his mind. It

is a matter of record that more than two thirds of the furnaces of the country were shut down within the next two years, and among them the Fairmount Rolling Mill.

For the next few years he was content to take charge of the property of other ironmasters and risk none of his limited capital. For two years he was Manager of the Renssalaer Iron Works, Troy, N. Y., which was the first rolling mill in the Empire State to make rails. It was a comparatively new industry in this country. Rails had been rolled at Mt. Savage, Md., in 1844, and the first T rails at Danville, Pa., in the same year. Cooper, Hewitt & Co., who built, and still operate, the Trenton Iron Works, rolled T rails in 1846.

They were the first in the world to make heavy rails, and rolled them up to 90 pounds per yard at that early period. One of these rails, made in 1846, was taken out of the track of the Camden & Amboy Railroad in 1898, after more than fifty years of service. Robert L. Stevens, President of the Camden & Amboy R. R. Co., put foreign made T rails into that road in 1836.

To the form, weight and stiffness of rails Mr. Smith gave much study and made some important changes in the rolls for rail making while at Troy. He became convinced, however, that the iron business could not be made successful at that place under the existing conditions, and severed his connection with the works.

Soon after, he went to Europe, partly to study the methods of manufacture and conditions of success in the various iron centers, and partly to determine whether Europe or America offered the greater advantages to a young man with limited capital. Going there well recommended, he was given abundant opportunities for collecting facts in relation to the iron business, which, with the experience he had already gained, gave him a comprehensive grasp of the whole subject. More than a year was spent in this study, and he pursued his inquiry with that zeal and careful attention to details which characterized his entire life.

He returned convinced that America offered the best

field for a young man's energies, and well equipped to meet the untoward conditions which surrounded the American iron manufacturer. He recognized the fact that, with a difference of nearly eight dollars a ton in labor cost in favor of Scotch pig iron, and a much greater difference in the labor cost of a ton of rails, the industry could not thrive in America without the fostering care of the general government. To secure that protection he bent all his energies, and on every occasion presented the data he had secured to show what might be done in the development of iron manufacture under proper conditions.

Soon after his return from Europe he became manager for Reeves, Buck & Co., in their rolling mill at Phoenixville. In the following December (1849) a convention of "Manufacturers and Dealers in Iron" was held in Philadelphia to take measures to relieve the depression of the iron interest by enforcing upon Congress the necessity for revising the tariff. The summer preceding this meeting had seen much agitation of this subject, and the names first affixed to the call for the convention were those of his employers, Reeves, Buck & Co., who were in full sympathy with the views of their manager.

Of this meeting Charles E. Smith and Nathan Rowland were secretaries. A committee on the State of the Trade and Statistics was appointed, of which Mr. Smith was chairman, and Stephen Colwell, was chairman of the committee on a Memorial to Congress. The reports of these two committees are marvels of clearness, not only in the marshalling of the facts presented but in their diction. They form an epitome of the knowledge of the iron industry of the period on both continents, and are a fitting beginning of the literature of the industry which has made America the arbiter of the world's destinies.

To Mr. Smith is due the credit of gathering and compiling these statistics with great judgment and consummate skill. He was quite willing to undertake the task of collecting the data from the scattered American manufacturers, but he had little conception of the labor and hardship which he afterward experienced in his quest for this information.

As shown in his report, he visited forty-five counties of Pennsylvania in which there were iron works, and obtained at first hand the statistics of their capacity, product and character of work turned out. When it is considered that there were but few miles of railroad in operation at that time, and that a large proportion of the forges and furnaces were inaccessible by stage lines and had but a local custom, and that only by diligent inquiry could they be located, the thoroughness with which this canvass was made, and the unquestioned accuracy of the report, must be regarded as little less than marvellous. Traversing the state three times from east to west and four times from north to south, by rail, by stage, by country wagons, on horseback and even on foot over mountains and through the wilderness, although the winter was one of the coldest of the century, he traveled over 2,500 miles and visited 504 charcoal furnaces, forges and rolling mills. The Convention had no funds. Starting with ten dollars of his own money he begged his way, paid his expenses and returned in the Spring with three hundred dollars in his pocket.

The report was made to Congress and was printed. The figures presented were drawn upon largely by the protectionist newspapers throughout the country. The Convention was chiefly useful to the iron manufacturers by bringing them to know each other and leading them to unite for the furtherance of their mutual interests. One of its most important fruits was the organization of the American Iron Association in 1855, of which Mr. Smith was elected treasurer and J. P. Lesley secretary. The Association undertook the compilation of a statistical guide to the iron works of the United States, the facts obtained being published in the Bulletin of the Association. These facts were, in 1859, presented in one large volume entitled the "Iron Manufacturer's Guide."

Of this volume, Mr. James M. Swank, the Vice-President of the American Iron and Steel Association, says: "In all this hard work Mr. Smith was the active and efficient assistant of Professor Lesley; in fact he may be said to have had from first to last, a leading share in the compilation of

the statistics gathered by the Association from 1855 to 1859. Because of this connection, and his previous work in collecting information of the iron industry of Pennsylvania in 1849, Mr. Smith was unquestionably entitled in his lifetime to the honor of being regarded as the first statistician of the American iron trade."

After lying idle for several years, the Fairmount Rolling Mill was re-purchased by Mr. Smith at sheriff's sale, and, under the name of Charles E. Smith & Co., he rehabilitated it, put in rolls for making railroad iron and also made skelp for his silent partners, Morris, Tasker & Co. He did not resume the manufacture of merchant bar, which was abandoned as unprofitable. The rails were principally light mine rails, not exceeding 50 pounds per yard. The very latest improvements were introduced and Mr. Coleman Sellers, who formed Mr. Smith's acquaintance about this time, said that William Sellers & Co. made for the mill a hot saw to cut the rails. It was one of the first to be put in use. Mr. Sellers said Mr. Smith showed much mechanical ability and seemed bent on doing the best possible with the plant, putting in not only the most efficient rolling machinery, but also other machinery to work the rails to completion.

The mill was equipped with puddle furnaces. As far back as 1846, when it was first built, the iron was boiled. Pig-iron, as it could be bought from the furnaces, was melted in deep furnaces. The molten iron was stirred, and iron scale (oxide of iron) from the mill was thrown into it; so that the output from the furnace of a good boiler would be greater than the weight of pig-iron put in. The skill of the furnaceman was best shown in his ability to collect the wrought iron in small balls, raise the heat so as to weld several of these balls into one, dip the ball out of the furnace, tilt the mass so as to let the slag run out, and do this so skilfully that the phosphorus would not be taken back into the iron. The ball was then taken to the squeezer or hammer.

About this time an automatic puddler was invented by Mr. William Sellers, but before it came into practical use the

Bessemer process was brought out, which, being a cheaper one, did away with puddling furnaces to a greater or less extent.

Improvements in the quality of the iron had been studied by Mr. Smith in an empirical way with fairly good results. The quality of the skelp made for Morris, Tasker & Co. was a matter of vital importance in the manufacture of tubes, and extraordinary efforts were made to hold their custom. They had put their money into the new venture, hoping the mill would turn out a product equal to that which they had hitherto imported. Some quite spirited discussions are said to have occurred between Mr. Smith and Mr. Thomas Tasker, the elder, in regard to the quality of the iron.

Mr. Washington Jones, of the Institute, who was a contemporary of Mr. Smith's, has a good recollection of the mills of that period. Reany, Neafie & Co., with whose establishment he was then connected, used to order iron from the Fairmount Rolling Mill. There was then but one other rolling mill near Philadelphia, that of Nathan Rowland & Co., and merchant bar only was made there. Mr. Jones made many alterations and repairs in Mr. Smith's mill while with Reany, Neafie & Co., and that firm built a 150 horse power engine for it in 1846, the first stationary engine they had ever built. The rail mill and rod mill were made by James C. Moore, the founder of the Bush Hill Iron Works. The latter rolled from $\frac{3}{16}$ to $\frac{5}{8}$ inches in diameter. Three-quarter and 1-inch rods were rolled by hand. It then cost $6.50 a day for the man who run the mill, and he spent about half that time at the "Nanny Goat Tavern" on top of the hill. Truly the conditions of success in iron manufacturing were lacking at that period.

Up to the time when Mr. Smith was called to the Presidency of the Philadelphia & Reading Railroad Company in 1861, he continued to manage the Fairmount Rolling Mill, an increasing proportion of its product going to the pipe works of Morris, Tasker & Co. After disposing of his interest in the mill it was run by Charles Wheeler, one of the members of that firm.

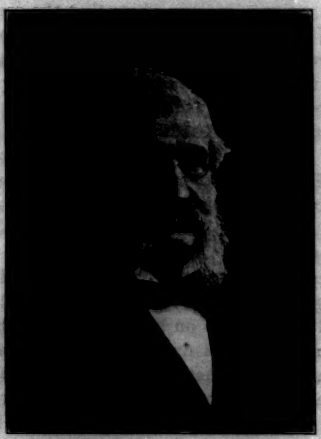
His selection as president of the Reading was a surprise to many, but his fitness for the position was well understood by those who made the selection. In 1852 he was elected to the Board of the Schuylkill Navigation Company, and for several years was an active member of that Board. The railroad was its competitor, and the questions constantly coming up for settlement between the two familiarized him not only with the advantages possessed by each, but convinced him of the desirability of uniting the two under one management. He was essentially a railroad man, his education and experience teaching him that the canals had had their day. Under his management the union was effected, and as the canals could not be improved without necessitating the rebuilding of both canal and floating equipment, they rapidly went out of use.

The history of the Reading Road under Mr. Smith's management has no parallel in respect to improvement in physical condition, development of natural resources along its lines, discipline of organization and successful financial results. He had spent all his life in the dual position of mechanical engineer and manager, putting his own conceptions into effect and profiting by the results. He made the track a fit highway for heavy traffic, adjusted the burden to every struggling industry on his lines, and faithfully turned into the company's treasury every dollar earned by its heavily laden trains. That he should have broken down in health after eight years of such labor is not surprising. His brilliant achievements while President of the Philadelphia & Reading Railroad are better remembered after the lapse of a third of a century than his earlier work in the development of the iron industry. The former is still a brilliant memory; the latter looks insignificant when comparison is made with the little rolling mill on the Schuylkill and its antiquated methods; but when the movement to organize the iron interests, in which he was the principal factor, is considered, together with the results which flowed from it, it may fairly be questioned whether that work ought not to be regarded as being the more important one.

JOHN LUCAS.

The subject of this sketch, who was one of Philadelphia's leading manufacturers, and prominently identified with the Franklin Institute and many other public institutions of the city, was born at Stone, Staffordshire, England, in 1823.

His early education was directed with the view of fitting him for commercial life. He appears to have early exhibited a preference for chemical studies, in which he became proficient, and thus laid the foundation for that successful



career as a manufacturer of paints and colors, on which he subsequently entered.

In 1844 Mr. Lucas came to America, and, after some time spent in Canada and other parts of the Western Continent, he finally settled in Philadelphia, in 1849, and shortly thereafter became a citizen of the United States.

He began his business career in this country as a foreign commission and shipping merchant representing several large European houses.

Mr. Lucas first began the manufacture of paints and

colors at No. 33 North Front Street, and, the venture proving successful, shortly afterwards removed to a larger building on Fourth Street, between Race and Arch Streets. His early acquired knowledge of chemistry greatly aided him in the development of this business, and the results of his continued technical study appeared in several letters-patent for improvements in the manufacture of paints and colors.

In 1852 he took Joseph Foster into partnership, and removed to 130 Arch Street. About this time he purchased a large tract of land in Camden County, N. J., which was noted for having a sheet of remarkably pure water upon it, which was of great use to him in producing superior colors. There he erected the since famous "Gibsboro Paint and Color Works" among the most extensive in the country.

His energy, business acumen and technical skill made it possible for him to utilize the natural advantages afforded by this favorable location to the best advantage, and the products of the house soon enjoyed a high reputation, and came widely into use.

In 1857 John Lucas was joined by his brother, William H. Lucas, and the establishment bearing his name at 141 and 143 North Fourth Street, is one of the largest and most important of its class in the United States.

Mr. Lucas was one of the pioneers in the development of Atlantic City, serving first as a director and then as the President of the Camden & Atlantic Railroad Company. He was an active member of the Society of the Sons of St. George, and for several years its president. He was warmly interested in the Hayes Mechanics' Home.

He was elected a member of the Franklin Institute in 1884, and for years was a frequent attendant at its meetings, in which he exhibited a lively interest. He was elected to the Board of Managers in 1889, and served until 1895, when his growing physical infirmities compelled him to decline further service.

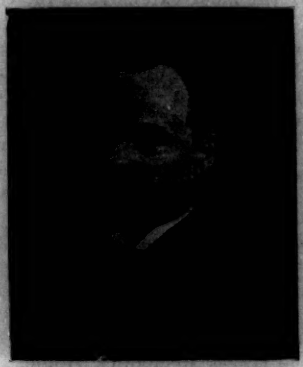
He married, in 1854, Harriet Annie Boun, of Philadelphia, daughter of Abraham and Ellen Boun, of , England. The fruits of this marriage were nine sons and six daughters. He is survived by twelve children.

Mr. Lucas was a man of most generous and humane impulses, genial in manner and of the most amiable and sympathetic disposition. His associates in the Franklin Institute sincerely mourn his loss.

WALDRON SHAPLEIGH.

Waldron Shapleigh, Chief Chemist to the Welsbach Company, and an esteemed member of the Franklin Institute, died on August 30, 1901, at his summer home in West Lebanon, Me.

Mr. Shapleigh was the son of the late Marshall Spring Shapleigh, and was born in Philadelphia in 1848. At an



early age he confined his education to the study of chemistry under the late Prof. J. P. Williams. At the age of 19 he was appointed as chemist to the Blair County Zinc Works in Pennsylvania, and a year later entered the Lehigh University as instructor of chemistry under the late Prof. Chas. M. Wetherill, whose place he temporarily filled upon his death. While at Lehigh University his interest was directed to the beet sugar industry, which was at that time engaging the attention of the scientific world. He resigned his position and went to France where he remained for two years so as to gain an intimate knowledge of this industry.

Upon his return to America he was engaged as chemist to the Kings County Sugar Refining Company, of New York, in whose employ he remained until the dissolution of the company, at the time of the formation of the American Sugar Refining Company. Shortly thereafter he accepted the position of chief chemist with the Welsbach Company, which company he served with great distinction until his death.

Mr. Shapleigh's connection with the Welsbach Company dated from the beginning of the industry in America, and it was during this period that he gained a wide reputation in scientific circles both in Europe and America, as the leading authority on the properties of the rare earths. His exhibitions of rare earths were recognized by the highest awards at all of the exhibitions in America and Europe.

During the Columbian Exposition held in Chicago, Ill., in 1893, Mr. Shapleigh acted as one of the judges of award in the Section of Chemistry.

He was a member of many scientific organizations, among which were the Chemical Society of London, Society of Chemical Industry, and Society of Arts of London; also of the American Chemical Society and the Franklin Institute.

Mr. Shapleigh was a man of unusual character, possessing a rare combination of strength and gentleness. All who knew him deeply loved and respected him, and have sustained a severe loss in his death.

He leaves a widow, a son and daughter.

NOTES AND COMMENTS.

USE OF KITES IN METEOROLOGICAL WORK.

London *Nature* has the following item of interest in reference to the latest developments at the Blue Hill Observatory, Mass., with the use of kites in meteorological investigations:

Until recently, no flights were made in winds having rates of less than twelve miles an hour; but Mr. A. L. Rotch, the Director of the Observatory, has now used the common method of creating an artificial wind and raising kites in comparatively calm weather by motion of the earth-end of the kite string or wire, the motion in this case being obtained from a rapidly moving

tug. The apparatus employed consisted of a portable windlass containing 3,600 feet of wire, three Hargrave kites having a total lifting surface of 80 square feet, and an instrument for recording temperature, pressure and wind velocity and humidity. This outfit was installed on the upper deck of a tug in Massachusetts Bay, on August 22d. Two flights were made and the greatest heights reached were 2,630 and 2,670 feet. With more wire and kites much greater heights could have been obtained. The natural wind varied between six and eleven miles an hour, and was much too light to elevate the kites and apparatus, but by steaming against the wind the velocity relative to the tug and kites was increased to between fourteen and nineteen miles an hour. In this artificial wind the kites rose easily, and so steadily that they could be let out from and hauled into hand without the slightest risk to kites or instruments. The kites were very sensitive to alterations of the course of the tug, and began to fall whenever the course varied 30° to 50° on either side of the mean direction of the wind. The experiment shows that meteorological records at great heights may easily be obtained during calms or very light winds by means of kites flown from a rapidly moving steamer; and that it is now possible for the observer and student to work uninterruptedly under almost all conditions of wind and weather.

LINEN MANUFACTURE IN THE UNITED STATES.

At a recent convention of the New England Cotton Manufacturers' Association the address of one of its members contained the recommendation that the manufacturers of that section of the country might find it profitable to turn their attention from cotton to flax. It is somewhat remarkable that, although the textile industries in this country have been very largely developed, especially within recent years, the linen manufacture seems to have had little share in this growth, and still remains practically in its infancy.

For this there are good reasons. Down to the period when the cotton manufacture by the factory system gained a foothold, the raising of flax for spinning and weaving was a widespread domestic industry, and nearly every household raised enough for its own needs. With the advent of cheap cotton goods the spinning wheel was relegated to the attic, the growing of flax for the household wearing apparel was abandoned, and the general knowledge of the process of treating the fibre became one of the lost arts.

At the present time the several large linen mills in this country are compelled to depend largely for their supply of raw material on imported flax.

The importation of linen goods into the United States represents an enormous sum annually, and it would seem the course of wisdom for the State and National legislatures to take suitable measure to encourage the establishment of the flax industry as a desirable domestic manufacture, as has been done with other branches of industry—notably the manufacture of tin plates—and with most satisfactory results.

In one respect the flax industry bears a resemblance to the sugar beet industry, namely, in that it requires for its successful introduction the active and intelligent co-operation of the farming community; but this difficulty has been readily overcome in the one case, and doubtless would not prove to be serious in the other. A large amount of flax is raised, especially in the West-

ern States, for seed from which the oil is extracted, so that the crop is one with which the farmers generally are familiar, but for the manufacture of fibre the flax must not be allowed to ripen its seed, but must be pulled up by the hand while green. The fibre of the ripe flax is found to be too coarse and harsh for producing fine linen, and the process of threshing out the seed breaks and tangles it so much as to make it unfit for anything but tow and paper stock. For the linen manufacture, therefore, the flax must be grown specially, the fibre must be specially treated, as will be described below, and the seed cannot figure in the crop.

A well-known and highly capable mill engineer, Mr. Samuel Webber, of Charlestown, N. H., and who has been prominently identified with the New England cotton manufacturing industry for years, has given in the *Boston Journal of Commerce* some interesting experiences bearing on the linen industry in the United States, which are so apropos to the subject of this article that they are quoted in part in what follows:

"It is in no way a difficult matter," says Mr. Webber, "to introduce the linen manufacture into New England so far as the mechanical operations are concerned; the only trouble will be in getting a proper supply of the raw material in suitable condition to be spun."

In 1880 Mr. Webber made a careful study of the linen manufacture in England, Scotland and Belgium to determine the question of the practicability of introducing the industry into this country. He thought then that the great objection would be the large amount of manual labor required to prepare the fibre for the mill. The treatment it must receive is thus described:

"Flax for spinning is not allowed to ripen its seed, but is pulled up by hand while green, and the stalks kept in bundles as pulled, are rotted, or 'retted' in shallow ponds or streams, being frequently carefully turned until the bark and woody parts of the stalk are so far decayed as to be readily broken and separated from the fibre when dry. This is done by a sort of wooden blade or sword, and is known as 'scutching.' The next step is 'hackling' or drawing the fibres through a set of steel combs, which take out the chips of bark and wood, and the fibre is then in bundles ready for the market. The operation of retting requires a good deal of wet and dirty manual labor. * * *

"There is no trouble in growing the flax. One of my earliest recollections, more than sixty years ago, is of linen clothes for summer made of flax grown, hackled, spun and woven by hand in this, my native village, and there then stood the remains of an old dam, or a brook, near the village known as the 'Oil Mill Dam,' where a previous generation had crushed the seed for the oil. * * *

"Wherever it (flax) is raised for manufacturing purposes great care is taken to keep the fibres smooth and parallel from the start all the way through, and the long bundles of fibre of which each apparent fibre of stalk is composed are kept together until the last operation of spinning, when the roving is run through hot water to dissolve the vegetable gluten before going to the drawing rolls which then pull them apart and deliver the fine yarn."

Referring to the co-operation of the farmers in the production of the raw material for the mills, Mr. Webber concludes as follows: "What is wanted

first is the distribution of samples of properly prepared flax through the agricultural districts, with an offer to pay the price for it for which it can be imported and to ascertain if the farmers will agree to produce in proper condition which it cannot be if ripened for seed " W.

TIN MINING IN THE MALAY PENINSULA.

A special mining commission of the London *Economist* reports as follows:

The lower half of the Malay Peninsula consists of the states of Perak, Selangor, Pahang, Negri Sembilan and Johore. The first four are known as the Federated Malay States—which are under the protection of Great Britain—and Johore will probably enter the Federation sooner or later. To the north of these are numerous other Malay states, quite unexplored as yet. These are nominally under Siamese influence, and are closed to European exploitation. The Federated Malay States, especially Perak and Selangor, contain by far the largest and richest tin mining fields known, and as they supply at present about four-sevenths of the world's output of tin their importance from the mining point of view can be easily imagined. These great tin deposits stretch from the north, through the independent Malay states, into Siam and the province of Yunnan, in China, and south into Sumatra, Banca, Billiton and other of the Dutch Indies.

A rough estimate of the world's present yearly supply of tin may be stated as follows:

	Per Annum. Tons.
Federated Malay States	45,000
Independent Malay States, Siam and Yunnan	4,000
Dutch Indies	15,000
Australia and Tasmania	3 000
Bolivia and Peru	4,000
Cornwall	4,000
Total	75,000

The question naturally arises: Is the output of tin going to increase? Will not the present high price before long have the effect of bringing many more producers into the market?

But tin is a metal which, relatively to copper, lead, silver and gold, is found in few countries, and I am inclined to think that the output, except in the Malay Peninsula itself, will not increase to any appreciable extent. In the Federated Malay States I can see no sign of waning in production, and when they are worked out, many years hence, the at present unexplored states in the north of the peninsula will doubtless continue to supply the world.

In the Federated States many of the richest patches of the alluvial tin bearing wash have already been worked out; but the lower grade areas, which now, owing to the higher price for tin, are as highly profitable to work as the richer ones used to be, appear to be of almost unlimited extent.

Every here and there you come upon one of these mines. From out of the big shallow holes thousands of Chinese coolies pour, carrying on their heads baskets of the tin-bearing gravel, which they empty into the sluices

and as the endless stream passes and repasses, one's belief in the permanence of this industry is crystallized.

On every side, too, you see dense tropical forests. One glance will tell you that, as this land is cleared and prospected, thousands of acres of alluvial tin carrying areas will be exposed, the existence of which is not now known. But the Government is very wisely putting a stop to the habit of taking up only the richest areas. The poorer lands must be worked out first, especially with the present high price for tin, and in days to come the output can be regulated and the revenue assured.

Practically the whole of the tin areas are owned and worked by Chinese, and some of the wealthiest proprietors now estimate their fortunes in millions of dollars. Europeans have found, by costly experience, that the Chinese coolie, in tin mining, will give a fair day's work only to a Chinese master, and unless they can introduce hydraulic sluicing profitably their share in the tin mining industry will be an insignificant one.

COMPARATIVE MERITS OF THE FLAME AND ELECTRIC SAFETY LAMPS FOR MINERS.

Mr. H. W. Halboum discusses in a late number of the *Colliery Guardian*, the present status of the miners' safety lamp. Comparing the improved forms of flame safety lamps of the Davy pattern with the electric glow lamp, he advocates the former as being preferable. For this unexpected condition he adduces the following reasons :

The old form of miner's safety lamp was not devised for the purpose of enabling the miner to remain for any length of time with impunity in an explosive atmosphere. The flame of the lamp cannot pass through the gauze and ignite the explosive gas without, but the gas can penetrate within the lamp and burn within the flame chamber. There is where one of the most valuable properties of the Davy and similar lamps is exhibited. The enlargement of the flame by the burning of the entering gas from without gives the miner immediate warning that he has entered a dangerous working, and enables him to leave the dangerous neighborhood and report its condition.

The electric lamp, on the other hand, gives absolutely no indication of the presence of dangerous gases, being completely enclosed and independent of the surrounding atmosphere. It is free from the danger of igniting the mine gases as long as it remains intact, but if broken, is liable to ignite the mixture without warning.

For these reasons Mr. Halboum is an advocate of the most improved forms of the flame safety lamp, such as the Massant or the Maeselar lamp, believing them to be more desirable. To meet this objection brought forward by Halboum, the advocates of the electric lamp propose the use in addition to it, of a separate indicator for "fire damp" and "choke damp." This, in his judgment, entirely qualifies all the advantages claimed for the new lamp.

He summarizes his comments on the subject in the following argument : "Every practical pitman at the present day will admit that the ordinary type of safety lamp constitutes a safety lamp chiefly because it betrays the character of the outer atmosphere. If an explosive atmosphere is present, we do not want a lamp that will burn, and a man who will attempt to work in such

an atmosphere. We want a lamp that will give indications of the presence of such an atmosphere, and a man who is not insane enough to attempt to work in an atmosphere which is lately unfit for respiration." W.

BURNING BY BECQUEREL RAYS.

It has been recently announced in the *Comptes Rendus* that the invisible rays emitted by radium have an active effect upon the human skin. It is well known that X-rays, if sufficiently intense and in sufficiently long duration of action, exercise a destructive action upon the skin, which peels off and leaves an open sore that is slow to heal. Recently Walkoff and Giesel observed a similar action exerted by radium. Mr. H. Becquerel now describes the effects noted by him on his own person. He carried a few decigrams of radiferous radium-chloride, inside a small sealed tube, in his waistcoat pocket for a total length of time amounting to about six hours. In ten days a red mark, corresponding in position to the location of the tube, developed on his skin. It was followed by peeling and suppuration, and the sore did not heal for a month. This will add one more to the cheerful list of possible skin diseases that civilization enables us to classify, develop and diagnose. In addition to the ordinary sun-burning which is prevalent in the northern hemisphere about this time of year, and is sought by giddy girls or callow boys, we have arc light burns, X-ray burns and Becquerel-ray burns. It seems likely that the action in each of these cases is similar, but a careful comparative investigation into the differences of action would probably be both useful and interesting. While the sun burns at a distance of ninety-odd millions of miles, the arc light and Crookes tube act at a few centimeters, and radium at a few millimeters.—*Electrical World.*

BOOK NOTICES.

The Phonographic Manual. By Charles Morrell. 8vo., pp. 490. Chicago: The Morrell Ve. 1901.

The author describes an improved system of shorthand writing, the modifications for accepted methods being based on certain original observations made by him. W.

Methods of Chemical Analysis and Foundry Chemistry. By Frank L. Crobaugh, M.S. 12m., pp. 79. Cleveland, O., 1901. Published by the author. (Price, $1.50.)

This hand-book for the foundry chemist is divided into two parts. Part I is devoted to analytical methods and suggestions, and Part II treats of the application of chemistry to foundry methods. The analytical portion treats of standardizing, sampling, and detailed methods of analysis of iron, phosphorus, manganese, calcium, sulphur, carbon, silicon and silica, aluminum and alumina, and copper.

Part II deals with the varieties of pig iron, coke and coals, figuring mixtures, figuring silicon, figuring sulphur, formulæ for castings, annealing, influence of elements in cast iron and the relation of the chemist to the foundryman. W.

Leçons sus les Moteurs á gaz et a Pétrole Faites á la Faculté des Sciences de Bordeaux. Par L. Marchis, Professeur adjoint de Physique à la Faculté des Sciences de Bordeaux. Un volume in-16 de xl-175 pages, avec 19 figures; 1901. Librarie Cauthier-Villers, Paris 1901. (2 fr. 75c.)

The work here entitled is a concise treatise on the theory and practice of the modern gas and oil engine. The theoretical side of the problem involved in this type of heat engine is elaborately discussed. W.

Cotton and Cotton Oil: Cotton; cotton-seed oil mills; cattle feeding; fertilizers. Profusely illustrated with original drawings. By D. A. Tomkins. Large 8vo, pp. 481. Charlotte, N. C. Published by the author, 1901. (Price $7.50.)

This work is the fourth of a series dealing with cotton and the associated industries.

The book is in three parts. Part I is a full treatise on the planting, cultivating and harvesting of cotton, and also a full discussion of all the present and prospective methods of ginning and baling cotton. The various round bale systems are fully illustrated and described. Part II deals with the manufacture and refining of cotton oil, and with the uses and final disposition of all the products. Part III is called "Correlated Industries," under which are grouped the fattening of beef cattle and the maintenance of dairy cattle on cotton oil products, and the manufacture and use of fertilizers. The use of home fertilizers, and the manufacture of commercial fertilizers each have full share of attention.

The book is profusely illustrated and is furnished with a good analytical index. The mechanical execution of the book is excellent. W.

The Telephone System of the British Postoffice. A practical handbook. By T. E. Herbert, A.M.I.E.E., etc. Second edition, revised with additions—with 156 illustrations. 12mo, pp. vii + 218. London and New York: Whittaker & Co., 1901. (Price 3d. 6s.)

The telephone trunk lines of Great Britain have been acquired and are operated by the State in connection with the postal service. This work was originally prepared to meet the needs of the employes of the postoffice, but was afterwards elaborated in book form. In embraces a number of chapters introductory to the subject of telephony in general, viz., the principles involved in the transmission of speech; the Bell telephone; transmitters and receivers, etc. Then follow a number of chapters devoted to the installation and operative details of the system. The present edition contains a new chapter entitled "Recent Advances in Switchboard Design." W.

A System of Phonoscript and Phonotypy. By Charles Morrell. Fourth Edition, 12mo., pp. 108. Chicago: Phonic Institute. 1890.

The author describes and illustrates in this little volume a system of phonetic writing and printing which will doubtless prove useful and suggestive to those who were interested in the reform of English orthography. W.

How to Become a Good Mechanic. Intended as a practical guide to self-taught men, etc., etc. By John Phin. Second edition, rewritten and greatly enlarged. 12mo., pp. 68, paper. New York: Industrial Publishing Company, 1901. (Price, 25 cents.)

The purpose of this work, as explained by the author, is to give to students who are endeavoring to pursue a course of study without a teacher a series of suggestions and hints as to "what to study, how to begin, what difficulties will be met and how to overcome them—in a word, how to carry on such a course of self-instruction as will enable the young mechanic to rise from the bench to something higher." W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, September 18, 1901.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 18, 1901.

Vice-President THEO. D. RAND in the chair.

Present, 84 members and visitors.

Additions to membership since last month, 9.

The gift was reported of a marble bust (with pedestal) of the late John Struthers, one time an active member of the Franklin Institute. The gift was accepted with the thanks of the Institute, and the Secretary was directed to make suitable acknowledgment to the giver, Mrs. Helen Struthers Dunn, of Philadelphia.

Mr. Wm. McDevitt, Inspector of the Philadelphia Board of Fire Underwriters, gave a series of illustrations designed to exhibit the causes of explosions at fires, especially where chemical substances, such as chlorates, nitrates, volatile oils, collodion, guncotton, etc,, are involved. The speaker drew largely upon his extensive experience with such explosions, and urged the importance of instructing workmen who handle dangerously inflammable or explosive substances in factories, etc., concerning their properties. The experiments made by Mr. McDevitt were striking and instructive. Discussed by Messrs. Fullerton, Goldschmidt and the author.

Then followed a series of informal communications on the Pan-American Exposition, which were profusely illustrated with the aid of lantern slides. The participants were Mr. Louis E. Levy, Dr. A. E. Kennelly, Prof. H. W. Spangler and Mr. Carl Hering.

Mr. Joseph Steinmetz exhibited a number of aluminium plates badly corroded by the action of sea waters. These had formed the hull plates of the American cup yacht *Defender*.

The exhibit demonstrated in the most effective way the unfitness of this metal for purposes where it is exposed to contact with salt water or to an atmosphere laden with such moisture.

Adjourned.

WM. H. WAHL,
Secretary.